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Aeronautical Engineering REVIEW

AUGUST, 1954

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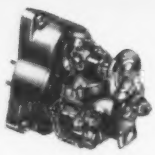

(Left) "Package-Type" Drive—can be strut or bracket mounted in line with power take-off pad.

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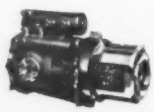

(Left) "Cartridge-Type" Drive—mounts within engine gear box.

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Aeronautical Engineering REVIEW

Vol. 13—No. 8 August, 1954

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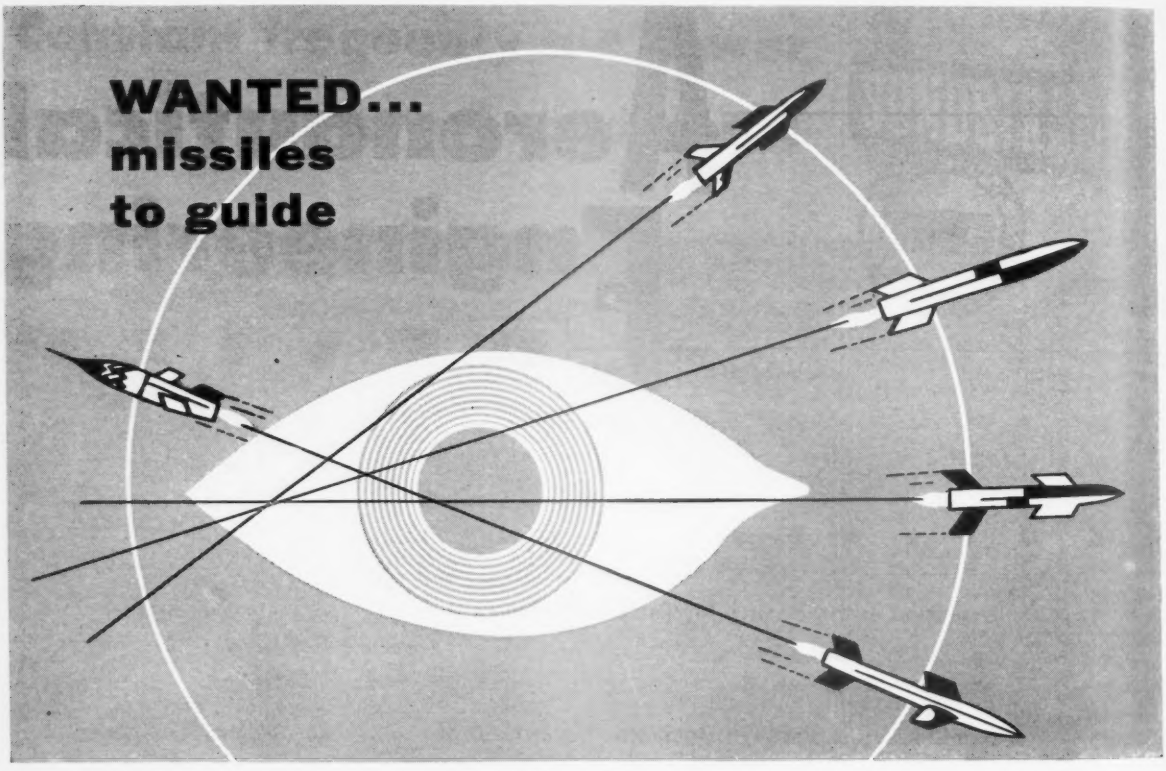

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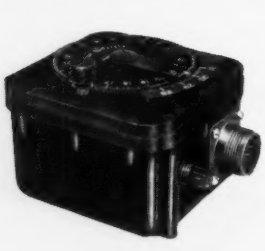

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IAS News

A Record of People and Events of Interest to Institute Members

Bane and Chanute Awards Presented

Dr. H. G. Heinrich and G. E. Cooper Receive Bane and Chanute Awards at June 23 Dinner During IAS National Summer Meeting in Los Angeles

The Thurman H. Bane Award for 1954

Dr. Helmut G. Heinrich, Aeronautical Research Engineer, Equipment Laboratory, WADC, USAF, was the recipient of The Thurman H. Bane Award for 1954 "for his outstanding accomplishments in the field of personnel parachute development."

Dr. Heinrich invented a personnel parachute that incorporates the first major design change in this equipment since its inception. The development of this parachute from an idea to a product ready for live testing took just 15 months. Known as the Personnel Guide Surface Parachute, it is a low-bulk stable parachute for personnel use at high bail-out velocities and utilizes the phenomena of interference drag and the guide-surface principle.

Dr. Helmut G. Heinrich

This Personnel Guide Surface Parachute has the lowest opening shock and the highest operational speed of all known man-carrying parachutes. It has been tested by USAF and USN personnel, and in over 800 jumps it exhibited a stability so superior that no injuries—not even a sprained ankle—were suffered.

Dr. Heinrich's invention is being tested by Martin-Baker Aircraft Company, Ltd., England, for the purpose of developing an automatic ejection seat for bail outs at 600 m.p.h. from a 250-ft. altitude.

The Thurman H. Bane Award, endowed by Major R. H. Fleet, honors the memory of Col. Thurman H. Bane, one of the most prominent technical officers of the U.S. Army Air Corps, who died in 1932.

The Octave Chanute Award for 1954

George E. Cooper, Assistant Chief, Flight Operations Group, Ames Aeronautical Labortory, NACA, was given The Octave Chanute Award for 1954 "for outstanding piloting and research at transonic and supersonic speeds resulting in increased understanding of transonic airflows and the problems of stability, control, and buffeting."

As an NACA Pilot and Research Scientist, Mr. Cooper has accomplished important research, especially in the critical fields of stability, control, buffeting, and airflow visualization. Seeking information in these fields, he has flown most of the current American military fighters, piloting them in many instances in the regions of flight previously unexplored and often with experimental alterations in the plane's configuration to study effects of changes of this type on transonic flight characteristics. He has also flown variable-stability airplanes with the stability made poor to aid in establishing boundaries of satisfactory, tolerable, and intolerable stability characteristics. In addition, he has also piloted a large number of tracking tests to establish in a more quantitative way the necessity for certain stability characteristics in airplanes.

Mr. Cooper has often worked out changes in piloting techniques and in aircraft configurations which have permitted the collection of data that otherwise would not have been obtainable. His many test flights have materially aided in providing a better understanding of transonic flight characteristics.

The Octave Chanute Award was established by the Institute in 1939 to honor the memory of Octave Chanute, pioneer American aeronautical investigator, who died in 1910.

George E. Cooper

Minta Martin Aeronautical Student Fund

Glenn L. Martin

Establishment of the Minta Martin Aeronautical Fund was announced by J. L. Atwood, President of the Institute of the Aeronautical Sciences, at the IAS National Summer Meeting Dinner held on June 23 in the Pacific Ballroom of the Hotel Statler, Los Angeles. This fund, amounting to $250,000, is a part of the original Minta Martin Endowment Fund first donated to the Institute in 1942 for the establishment of an aero-medical research laboratory. Because the original purpose of the Minta Martin Endowment Fund could not be carried out, it has been made available for other purposes.

Glenn L. Martin, donor of this fund and Founder of The Glenn L. Martin Company, was one of the honored guests at the National Summer Meeting Dinner. In commenting on the announcement, Mr. Martin said, "The establishment of this fund is in keeping with the ideals of my late mother, Minta Martin, who from the beginning demonstrated a great interest in young people in aviation. By making this fund available to the Institute of the Aeronautical Sciences, its efforts in preparing the student engineer for his place in the aeronautical industry will be facilitated. It is my hope that this fund will benefit aeronautical students throughout our country for many years to come."

An Advisory Board has been appointed to approve the administration of the earnings of the Minta Martin Aeronautical Student Fund. This board consists of Mr. Martin; T. P. Wright, Vice-President for Research, Cornell University; the IAS President; and the Director of the Institute.

Mr. Martin, in addition to being an IAS Benefactor, is also an Honorary Fellow and a Founder Member of the Institute.

IAS Flight-Test Engineering Fellowship Announced

At the National Summer Meeting Dinner of the Institute of the Aeronautical Sciences held June 23 at the Hotel Statler in Los Angeles, J. L. Atwood, IAS President, announced the establishment of an IAS Fellowship in Flight-Test Engineering. He stated that the support for this fellowship comes from a donor who wishes to remain anonymous.

The need for fellowships of this type is apparent in view of the complexity of today's aircraft. At one time, the only requisite for a test pilot was simply piloting experience. Today, however, the situation has completely changed, and the test pilot must also be an engineer with special training of a high technical order. As a flight test engineer-pilot, he must know at all times what is going on around him in all regimes of flight so that he can properly assess the behavior of the aircraft and can intelligently report his observations to engineers and designers on the ground.

The IAS Fellowship in Flight-Test Engineering covers 2 years of graduate research work at a school or university where an appropriate curriculum has been established. It is awarded on a competitive basis. Regulations pertaining to Fellowship applications are being distributed through all IAS Sections and Student Branches.

A Board of Award has been appointed to consider applications. This board consists of Dr. Hugh L. Dryden, Director, NACA; Roger W. Kahn, Grumman Aircraft Engineering Corporation; and S. Paul Johnston, Director of the IAS.

At the same time, Mr. Atwood announced the first recipient of this IAS Fellowship. He is David George Powell, a 1954 honors graduate in aeronautical engineering at Princeton University. After a summer's practical experience at the El Segundo Plant of Douglas Aircraft Company, Inc., Mr. Powell will continue his work at Princeton in a curriculum that, during the past 7 years, has been highly successful in training engineering test pilots for the United States Air Force and United States Navy.

St. Louis Section's First Annual Student Paper Competition

The St. Louis Section, in keeping with its policy of promoting aviation in the educational institutions of the Midwest, held its First Annual Student Paper Competition during the spring semester of 1954. All undergraduate engineering students from colleges and universities of 15 Midwestern states were invited to participate in the competition.

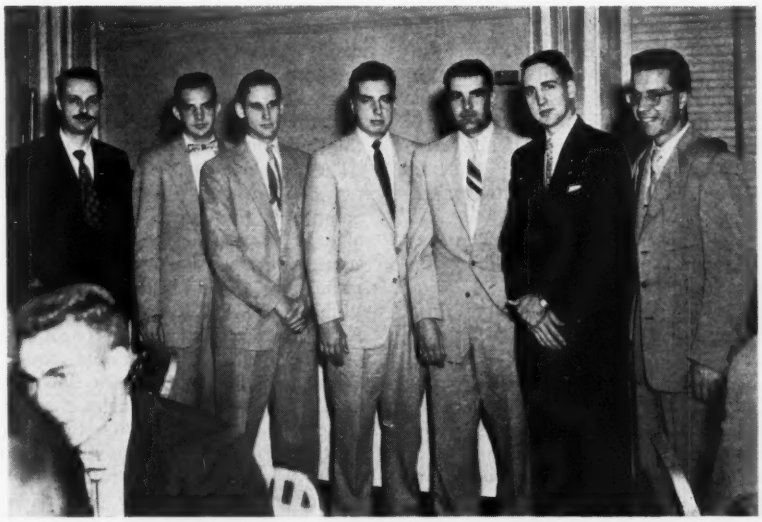
To handle the evaluation of the papers and the selection of the winners, the St. Louis Section established a Board of Judges, which included Prof. C. J. Kippenhan, Washington University, Chairman; John D. Weaver, McDonnell Aircraft Corporation; and Darrel Massey, Westinghouse Electric Corporation.

Six winners were chosen, the first three receiving cash prizes, and the other three being given Honorable Mention. The cash prizes were: First Prize, $250; Second Prize, $150; and Third Prize, $100.

The competition culminated on May 26 in the presentation of the winning papers and the awarding of the prizes.

The response by the students to the competition was gratifying. In all, 21 applications were received, 17 of which were accepted for consideration by the judges. These 17 papers came from eleven colleges in seven states.

The following are the winners of the competition and the titles of their papers:



The three winners and the three receiving Honorable Mention during the St. Louis Section's First Annual Student Paper Competition are shown with John H. Meyer, Chairman of that Section. From *left to right* are: Mr. Meyers; Stephen R. Dvorchak, Parks College, Honorable Mention; Kenneth G. Wernicke, University of Kansas, Third Prize; William L. Fisher, University of Michigan, Second Prize; Orvid R. Spoering, University of Kansas, First Prize; George R. Inger, Wayne University, Honorable Mention; and Richard Ross, University of Wichita, Honorable Mention.

First Prize—Orvid R. Spoering, University of Kansas, "The Design of a Mach-Zehnder Interferometer"; Second Prize—William L. Fisher, University of Michigan, "Climb Performance of Aircraft as Applied to Interception"; and Third Prize—Kenneth G. Wernicke, University of Kansas, "A Determination of the Boundary-Layer Temperature Recovery Factor on a Flat Plate in Supersonic Flow." Those receiving Honorable Mention are: Richard Ross, University of Wichita, "Boundary Layer Control"; Stephen R. Dvorchak, Parks College, "Comments and Observations on the DeLanne Configuration"; and George R. Inger, Wayne University, "The Sonic Bang."

This picture was taken at the May 26 Dinner Meeting that climaxed the St. Louis Section's First Annual Student Paper Competition. Shown *from left to right* are: John H. Meyer, Chairman, St. Louis Section, and Chief of Structures, McDonnell Aircraft Corporation; Vernon Outman, Member, St. Louis Section Advisory Board, and Chief Technical Engineer, McDonnell; Comdr. Charles A. Van Dusen, USN, Staff, Chief of Naval Operations, Principal Speaker; and Kendall Perkins, Member, St. Louis Section Advisory Board, and Vice-President—Engineering, McDonnell.

Eight students, including all the winners, accepted the invitation of the Section to participate in the May 26 activities. In the afternoon, the winners presented their papers before a joint meeting of the St. Louis Section and the Parks College Student Branch, with Lloyd Gish, Chairman of the Student Branch, presiding. John H. Meyer, Chairman of the St. Louis Section, introduced the winners. The meeting was held in the Parks College Auditorium in East St. Louis, Ill.

The visiting students were also treated to an extensive tour of the McDonnell Aircraft Corporation. Commander P. V. Aaronson, Executive Officer, NAS, St. Louis, arranged accommodations for the students at the Naval Air Station at Lambert Field.

On the evening of May 26, the St. Louis Section held its Annual Dinner

(*Continued on page 100*)

Fifth Southeastern Student Branch Conference

The Fifth Annual Southeastern Conference of the Student Branches of the Institute of the Aeronautical Sciences was held at the Alabama Polytechnic Institute, Auburn, Ala., from April 15 to April 17. During the 3 days, students and faculty members from Virginia Polytechnic Institute, Georgia Institute of Technology, University of Florida, University of Alabama, Mississippi State College, and Alabama Polytechnic Institute presented papers on aeronautical subjects.

Registration was held on Thursday afternoon, April 15, in the lobby of the new Student Union Building.

The first session was opened on Friday morning in the auditorium of Duncan Hall, headquarters of the Extension Service of A.P.I., with a welcoming address by J. E. Hannum, Dean of the School of Engineering. The first paper, presented by Rayford R. Sanders of A.P.I., was entitled "Elements of Flight Instruction." The second paper, "Some Factors in the Design of Subsonic Turbojet Ducts," was presented by LeRoy Fuss III of Georgia Tech. "An Electro-Chemical Method of Visualizing Flow in Water and Application to Boundary Layer Studies," by Edward W. Geller of Mississippi State College, was offered as the third paper of the morning. Following a coffee break, Gerald Upton of V.P.I. presented a paper on "Pressure Distribution About Diamond Airfoils in a Two-Dimensional Incompressible Flow." The last paper of the morning was "Design of a Sting-Type Wind Tunnel Balance," by Ed L. Battle of A.P.I.

After lunch, five more papers were presented by the delegates. The first, by Floyd Bennett of V.P.I., was entitled "The Transonic Similarity Laws." The second, "Performance Measurements at Low Reynolds Numbers," was presented by Gilbert H. Hoffman of Mississippi State College. The third, presented by William R. Knepshield of the University of Alabama, was entitled "The Development of Titanium Alloys for Use in the Aircraft Industry." Samples of titanium alloys were available for comparison with other structural materials. Following a short intermission, Donald Elliot and Milton Windler of V.P.I. presented "The Aerodynamic Characteristics of an Airplane Model with Variable Swept Wings." Slides were shown illustrating the effect of various angles of swept wings. The last paper for the day, entitled "Fifty Years of Aircraft Structures," was presented by Prof. John W. Hoover of the University of Florida. Slides were shown illustrating aircraft structures from the first early models to present-day modern aircraft.

Friday evening a banquet was held in the Student Union Building. Dr. Ralph B. Draughon, President of the Alabama Polytechnic Institute, introduced the guest speaker of the evening, Dr. Martin Schilling, Chief of the Technical and Engineering Division at the Redstone Arsenal. Dr. Schilling's talk on guided missiles was well illustrated with slides on performance and design data. Along with the slides, movies were shown of the development of the German V-2 rocket and American guided missiles.

Saturday morning presentations resumed with a paper on "Tension Skin Construction," by Frank L. Clark of the University of Florida. The second paper, "Synthesis of a Preliminary Empirical Relation Between Aerodynamic Losses and Their Accompanying Sound," was presented by Richard C. Eldredge of Mississippi State College. "The Strain Gage as a Research and Educational Tool," by Thomas C. Nylund, University of Alabama, was given as the last paper of the conference.

A business session was held following a short intermission, and it was decided that the Virginia Polytechnic Institute would be the site of the next conference. The conference was then adjourned until next year.

Preparation for a conference of this type consists of much planning and correspondence among the schools involved. Titles of papers and time limits must be decided upon before the conference convenes. Arrangements for housing, guest speakers, and auditoriums must be made well in advance. We, of the Alabama Polytechnic Institute, feel that our efforts were well rewarded by the quality of the papers presented and the smoothness with which the conference ran. To the delegates of of each school, our thanks for making this possible.

ARVID L. WAHLQUIST,
Chairman
RAYFORD R. SANDERS,
Vice-Chairman
IAS Student Branch,
Alabama Polytechnic Institute

News of Members

▸ **Rear Admiral Calvin M. Bolster, USN (Ret.)** (F), Coordinator of Development, The General Tire & Rubber Company, was awarded a Gold Star in lieu of a Second Legion of Merit medal. The citation accompanying this award reads in part: "For exceptionally meritorious conduct in the performance of outstanding services to the Government of the United States as Chief of Naval Research, Washington, D.C., from 1 August 1951 to 30 December 1953." Among the projects carried out during his tenure as Chief of Naval Research were the "establishment of a unique system of vast significance in the field of anti-submarine warfare" and the compilation of a detailed report on the Navy's Air-to-Air Guided Missile Program.

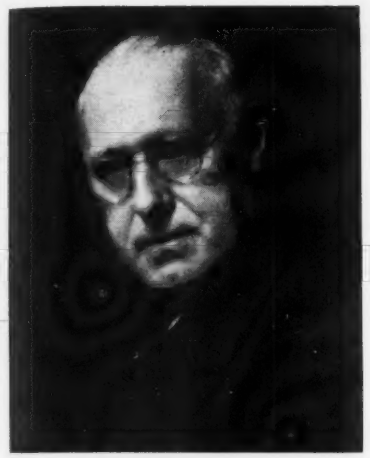
▸ **Reginald Alfred Charles Brie** (AF), Official-in-Charge, B.E.A. Helicopter Experimental Unit, British European Airways Corporation, England, won the British Silver Medal for contributions to the development of the rotary-wing aircraft. The medal was presented to him by the Royal Aeronautical Society.

▸ **R. Gordon Campbell** (M), Assistant Professor of Aeronautical Engineering, Rensselaer Polytechnic Institute, began a program of research on June 1 for The B. F. Goodrich Research Center. Mr. Campbell is conducting an extensive series of wind-tunnel tests as part of a general study of the aerodynamic effects of pneumatic wing deicers on aircraft performance. The research project continues for a year.

▸ **George F. Chapline** (F), Vice-President of Fairchild Engine and Airplane Corporation and General Manager of the Fairchild Engine Division, has accepted sponsorship of the 1955 Aeronautic Production Forum of the Society of Automotive Engineers. This Forum is currently scheduled for New York in April of next year.

▸ **Sir A. H. Roy Fedden** (HF), Aero-Engine Designer, England, has been given an Honorary Fellowship diploma by the Royal Aeronautical Society.

▸ **Calvin A. Gongwer** (M), Manager, Underwater Engine Division, Aero-



A $50,000 scholarship fund, honoring Lester Durand Gardner, has been established by Massachusetts Institute of Technology. Known as the Lester Durand Gardner Scholarship Fund, it will be used for the support of either undergraduate or graduate fellowships, depending on which need is greater. This fund was set up out of the school's unrestricted funds in recognition of the loyal service and many contributions given to M.I.T. by Lester Durand Gardner, IAS Founder, Fellow, Founder Member, and Benefactor and M.I.T. alumnus.

jet-General Corporation, Subsidiary of The General Tire & Rubber Company, was one of 20 men selected in a recent *Fortune* magazine poll as the top young scientists in U.S. universities and industry. Mr. Gongwer received his M.S. degree in Mechanical Engineering from California Institute of Technology in 1939.

▸ **A. Griswold Herreshoff** (M) retired last May from his position as Executive Engineer in charge of Development Design, Chrysler Corporation. Mr. Herreshoff was with Chrysler for more than 27 years.

▸ **Hall L. Hibbard** (F), Vice-President—Engineering, Lockheed Aircraft Corporation, has been elected a Fellow of the Royal Aeronautical Society.

▸ **Henry Bernon Howard** (M), Assistant Director of Research Structures, Ministry of Supply, England, has been awarded the Bronze Medal of the Royal Aeronautical Society for long and valuable work on aircraft structures.

▸ **Charles H. Kaman** (M), President, The Kaman Aircraft Corporation, has been given the Connecticut Junior Chamber of Commerce "Distinguished Service Award." Mr. Kaman was cited for "his outstanding contribution to Connecticut in founding and guiding what has become one of Connecticut's leading industrial enterprises."

▸ **Dr. Albert E. Lombard, Jr.** (F), Scientific Adviser, Directorate of Research and Development, Headquarters USAF, has been elected Chairman of the Executive Council of the Central Radio Propagation Laboratory, National Bureau of Standards. This organization is the primary agency of the U.S. Government for research and development in radio-wave propagation, centralization and coordination of propagation information, and development and custody of the national primary standards for electrical quantities at radio frequencies.

▸ **Andre A. Priester** (F), Chairman of the Technical Committee, Pan American World Airways, Inc., was elected First Vice-Chairman of the Technical Committee of the International Air Transport Association.

Necrology

Gerald R. Brady

Gerald Robin Brady, TMIAS, Flight-Test Engineer with the Aerophysics Laboratory, North American Aviation, Inc., died from injuries received in an accident.

He was born on February 3, 1923, in Los Angeles, where he attended the James A. Garfield High School from 1938 to 1941. In April of 1950, he enrolled as a student at the Northrop Aeronautical Institute, from which he was graduated 2 years later. He joined North American's Aerophysics Laboratory in May of 1952.

Mr. Brady held CAA Commercial Pilot's Certificate No. 244496. He is survived by his wife, Mrs. Evelyn J. Brady.

Major Gen. Oliver P. Echols

Major General Oliver P. Echols, USAF (Ret.), FIAS, Chairman of the Board, President, and General Manager of Northrop Aircraft, Inc., died on May 15 of pneumonia and complications. He was buried in the Arlington (Va.) National Cemetery.

Major Gen. Oliver P. Echols

Born in Charlottesville, Va., on March 4, 1892, General Echols studied at the Virginia Polytechnic Institute and was graduated in 1913 from the University of Virginia. In 1916, he entered the U.S. Army as a Second Lieutenant and during World War I served with the American Expeditionary Forces in the Signal Corps' Aviation Section. He continued in the armed forces as a career officer and in March of 1942 was appointed Commanding General of the Air Materiel Command. The following March, he was named Assistant Chief of Air Staff in charge of materiel, maintenance, and distribution. At the time of his retirement from the U.S. Air Force in December of 1946, he was Director of the War Department's Civil Affairs Division.

General Echols joined Northrop as Chairman of the Board in February, 1949, after serving as President of Aircraft Industries Association. Some time after coming to Northrop, he assumed the responsibilities of General Manager and in November of 1952 was elected President of the corporation.

General Echols is survived by his wife, Mrs. Margaret Bailey Echols, a daughter, Mrs. Mary Echols Simpson, of Fort Benning, Ga., five brothers, a sister, and two granddaughters, ages 3 and 2.

Benarthur C. Haynes

Benarthur Castle Haynes, MIAS, died of acute pancreatitis on April 29. He would have been 45 years old on the following May 23.

Mr. Haynes was born in Santa Fe, N.M., where he attended grammar and high schools. After being graduated from Santa Fe High School in 1927, he matriculated at the California Institute of Technology. There he was awarded a B.S. degree in Mechanical Engineering in 1932, an M.S. degree in Mechanical Engineering in 1933, and an M.S. in Meterology in 1936. He attended Cal-

(*Continued on page 72*)

Guest Editorial

OUR SHRINKING GLOBE

Excerpts from Address
by

Donald W. Douglas
President, Douglas Aircraft Company, Inc.

Institute of the Aeronautical Sciences
National Summer Meeting Dinner
June 23, 1954

IAS President Lee Atwood, Dinner Chairman.

A great many things have happened to aviation and to our world in the years since the first round the world flight 30 years ago. This flight, which then took 179 days from Santa Monica to Santa Monica, could now be made in four days, and, in a few years, in not over two. The time is not far off when any place on this earth can be reached from any other in not over 24 hours. And if one can accept at face value the predictions of qualified scientists and engineers, it will be possible before long to establish a satellite in space which will circle the globe continously, passing over a given spot every four hours or six times the rate of the moon....

We whose work lies in the aeronautical sciences must all have asked ourselves many times whether we are agents of death and destruction when we have seen the uses to which our products have been put. The answer, I think, is simply this: We know in our hearts that we as individuals, and the great body of mankind as well, are far from being warmongers. Left to ourselves we could not, with a few exceptions, be spending our substance inventing and building means capable of obliterating the other fellow. The trouble is with the few exceptions. On a small scale, that is why we have our local police force. On a large scale, it is why we have our national defense establishment and all that goes with it.

Personal and group experience has taught us that certain aspects of human nature have to be restrained by force if there is to be law, order, and what our forefathers called the pursuit of happiness. So we realize that an essential part of life has been, from the beginning, and always will be to the end of time, protection against evil. We are certain that our form of government and the public opinion that supports it will never permit our military forces to be used aggressively. They will be used only in self-protection and then only to the extent dictated by the nature of the specific threat....

We fought in World Wars I and II as unwilling last-minute participants, and we took months and years in each instance to mobilize our full power to strike back. The production potential of this country was the weapon that eventually turned the tide after long months of enemy success. We built up our production and our military might behind the shield of our allies

Donald Douglas presents model of 1924 World Cruiser to Los Angeles Section Chairman, R. R. Heppe.

and of distance. Now this time factor has been lost, and it is not safe to plan any defense on the basis of something that will be built up after hostilities start. The forces with which we strike back must be in existence and in readiness at all times. Moreover, they must be able to strike back after they have sustained the first blow, for one of the rules of the game, which is at the same time our weakness and our strength, is that we grant the enemy the first blow....

It would, of course, be of great assistance in doing this with ease and dispatch if we and our allies had a world-wide system of air transportation in continuous peacetime use in the interests of commercial trade and travel. Such a system is now in operation, but much can be done to expand it and to integrate its operations and facilities with those of our military air transport system. To the extent that one complements the other, the total cost will be reduced, and the effectiveness in maintaining peace will be greater.

It is not yet possible to think of this shrinking world as one world. Not through our own choice but in spite of our best efforts it is divided into two parts, with great restrictions on communication and travel between them. We can hope that this will not always be so, and we can work and wait for this to come about, but in the meantime we must live with things as they are. This means to me that we must stimulate normal trade, communication, and intercourse to the best of our ability to the end that the general level or standard of living throughout the world gradually improves, meanwhile making it unattractive for the forces of aggression to operate....

Technology has never advanced as rapidly as it is advancing right now. We know what has been accomplished in the last 30 years. We know how much smaller our globe already has become. The future is yet to be written. We in this industry must realize it is our prime responsibility that our part of the writing must be well done. Our page in history may well be the most vital and important, or, if we fail, could be the last....

In building civil transports we have always present in our minds that nothing is too small, nothing too expensive, that everything must be the best and the safest. No chances can be taken with unsound or unproved

(Continued on page 62)

Evolution of the Boeing Jet Tanker-Transport *Design*

by

MAYNARD L. PENNELL*
Boeing Airplane Company

THE DESIGN OF ANY NEW AIRPLANE, no matter how much of a departure it may be from present practice, has its roots deep in the past. It represents an evolutionary process. It is related to all the development that has taken place within the industry and, more particularly, to the developments within the company which gives it birth. Its inheritance from the industry as a whole gives it general form; its inheritance from the company gives it character.

To trace the influence that the evolutionary process in industry has exerted on Boeing's jet tanker-transport prototype would be to emphasize the obvious; it is enough to say that the emphasis on speed in this design is typical of what has been the "next step" throughout aviation history. It is out of this never-ending quest for more speed that the growth of the industry has come.

To recount in detail Boeing's part in the industry would be interesting but not within the intent of this article. It should be recalled, however, that from the very early days of Boeing Airplane Company there has been a pioneering spirit evident in Boeing designs. Examples are the P-26, the first monoplane fighter airplane produced in quantity, and the Y1B-9A bomber, the first monoplane bomber and the first bomber to exceed 200 m.p.h. top speed. In transports, there was the Monomail experimental airplane, followed soon after by the production Boeing Model 247's, the first of the modern transports. Later in the thirties came the B-17, the first production four-engined bomber; and at about the same time came its transport sister, the Model 307 Stratoliner, which inaugurated the new era of pressurized flight on the airlines. The models that grew out of World War II and the early postwar years—the B-29, B-50, C-97, and Stratocruiser—established new records of effectiveness as bombers and new standards of luxury and utility as transports. In addition, the KC-97 Stratofreighter was the first tanker-transport airplane, and is today the only tanker being procured in production by the Air Force.

Shortly after the war, Boeing produced another "first," the B-47 Stratojet—the first multijet swept-wing bomber. This was followed by the B-52 Stratofortress, the first jet intercontinental bombing weapon. At this time, in considering the future of the country's and the company's airplane program, it appeared obvious to Boeing management that there was a need for a sister ship for the B-47 and B-52, to provide new standards of speed and efficiency in the transportation of personnel and materiel.

But many questions had to be answered before Boeing could know that such a transport would be feasible. Would such a plane be economical? Could it compete with today's most efficient transports on a dollars-and-cents basis? What would it have to offer in the way of

* Chief Project Engineer—Aircraft.

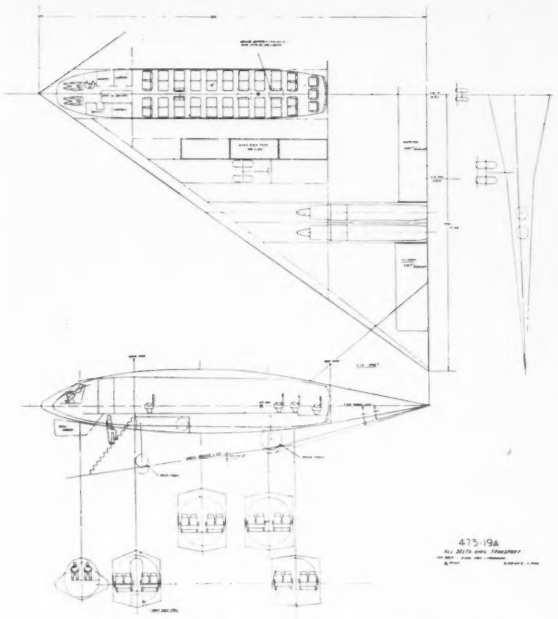
customer appeal? Could it be made as safe or safer than today's transports? Could it operate reliably and maintain a schedule? Could it have take-off, flight, landing, and ground-handling characteristics comparable to today's best transports? Could it be efficiently maintained? When should a project to design and build a jet transport be started, and how should it be financed?

The answers to these and other questions were reached over a period of many months. During this time a great variety of engineering studies was conducted and frequent discussions with military and civilian air transport personnel were held in order to obtain as broad a picture of design requirements as possible. In determining the answers to its questions the engineering staff at Boeing evolved the present jet tanker-transport prototype.

In the course of this investigation, Boeing engineers found that many erroneous impressions existed regarding jet aircraft in general and the potentialities of jet transports in particular. This was especially true regarding the question of economy. It had been assumed that jet engines were basically inefficient and that the design compromises necessary in order to achieve high speed were such that this type of power was useful only for military combat aircraft, where tactical considerations justified the "luxury" of very high speeds. However, detailed study revealed that the fuel consumption of the best modern jet engines is only 20 per cent or so higher per thrust horsepower hour than that of the typical present-day reciprocating engine-propeller combination. In addition, the jet engine makes possible a reduction in basic airplane drag as a result of its small size and the elimination of disturbances from the propeller slipstream.

Even compared to the compound reciprocating engine and propeller at best cruising speed and altitude, the better jet engines use only about one-third more fuel per equivalent thrust horsepower hour. When one considers the cost of jet fuels—only 70 to 80 per cent as much as high-octane aviation fuels—the difference in operating cost from this factor very nearly disappears.

The Boeing Model 473-1, first of the Model 473 series to be studied by Boeing Airplane Company preliminary design engineers, dates back to 1947. It introduced the series, which was one of the two design series that converged later to evolve into the design of the Boeing jet Stratotanker-Stratoliner prototype recently completed. The earliest Model 473 was a twin-jet design with wing span of 79.5 ft. and gross weight of 48,500 lbs. Powered by engines of 6,000-lbs. static thrust, the airplane would carry 27 passengers, engineers calculated.

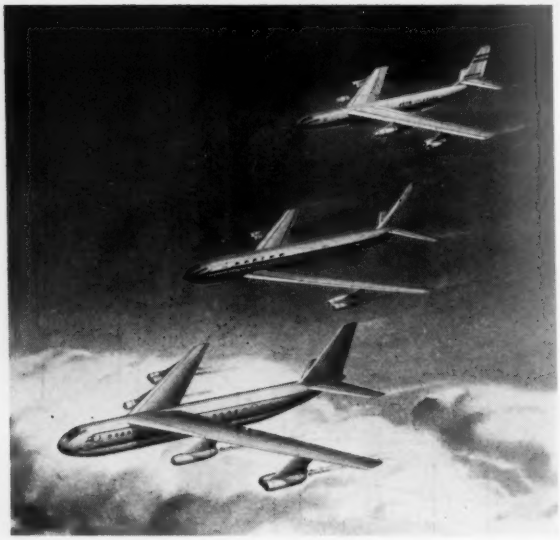


Delta wing configuration was not neglected in the search by Boeing Airplane Company engineers for the best possible jet transport design. Here is a delta wing design, the Model 473-19A, which was drawn early in 1949. Span was 110 ft., gross weight was 145,000 lbs., and passenger capacity 60 persons. Although this design did not go far, it too added to the design knowledge behind the present Boeing jet tanker-transport prototype.

Speed and pay load are principal factors in the earning capacity of an airplane. Speed is a highly favorable factor since, if one transport can travel twice as many miles per day as another transport comparable in size and pay load, revenue will be twice as great. We found that a jet transport could be designed that would be able to fly at twice the speed of today's transports. We also found in our studies that jet transports could be designed which would carry considerably more pay load over the same distance than most present-day transports. Considering both speed and pay load, it appeared that the work capacity of our probable jet transport would be three or four times that of the larger present-day transports.

Another factor to be considered was maintenance. Although operating experience with jet engines was somewhat limited, there appeared to be no reason why they could not be at least as trouble-free as reciprocating engines. On the air-frame side of the picture, our experience with military aircraft led us to believe that maintenance should be no more of a problem than with reciprocating engine-powered airplanes of the past.

But what about the reportedly high initial cost of a jet transport? This would have a bearing on amortization and insurance costs in the operating cost formulas. Our studies indicated that, in relation to the work capacity of the jet transport, the initial cost was less than that of comparable transports of today, even though the cost of many of today's transports reflects the bene-



Artist's conception of three Boeing jet transport designs on the drawing boards in Boeing Airplane Company's preliminary design unit in 1950. These designs are based on the Boeing B-52 wing.

ficial effect of long experience in building a specific model or type.

The evidence in favor of jet transports was so strong that we could only conclude that we were dealing with a fundamentally sound and economical method of air transportation for personnel, cargo, or any other load, military or commercial.

But there was another side to look at—what might be called the more glamorous side of the picture. What special advantages would a jet transport airplane have?

First on the list comes speed, the fundamental reason for most air transport. In the movement of either people or goods, there is an advantage in being able to get to the destination as quickly as possible. This is true for either military or commercial loads, though the reasons may be especially compelling in the case of military problems. Of course, in such specialized military applications as the tanker aircraft, there is a particular advantage in being able to match the speed of the combat aircraft that is to be refueled. A jet transport would have this advantage.

Boeing engineers inspect a flexible test model of the Boeing jet Stratotanker-Stratoliner prototype. From *left to right*, Edward C. Wells, Vice President—Engineering; George S. Schairer, Chief of Technical Staff; J. E. Steiner, Preliminary Design Engineer; Maynard L. Pennell, Chief Project Engineer—Aircraft; and E. M. Storwick, Wind-Tunnel Operations Engineer.

Comfort was another advantage seen in jet transport. It appeared certain that a high level of comfort could be achieved since vibration and noise levels, especially in cruising, would be very low, and operation could be at altitudes where weather conditions would ordinarily be ideal.

Safety was another advantage we recognized in our probable jet transport. We measured the airplane characteristics against the standards established in Civil Air Regulations for reciprocating-engined aircraft. The jet transport was found to meet or exceed these requirements easily. In particular, the effects of engine failure during take-off, climb, or cruise, in all cases studied, proved to be far less serious than in the case of other types of airplanes considered. This is due to the fact that the engine size, selected on the basis of desired cruise speed and efficiency at altitude and take-off distance, resulted in a large amount of reserve power for climb. While the total thrust of the ordinary propeller-driven airplane reduces as speed increases, the jet-powered airplane's engines provide nearly constant, or increasing, thrust as speed increases. In addition, there is no danger of drag and other detrimental effects of a windmilling propeller in a jet-powered airplane.

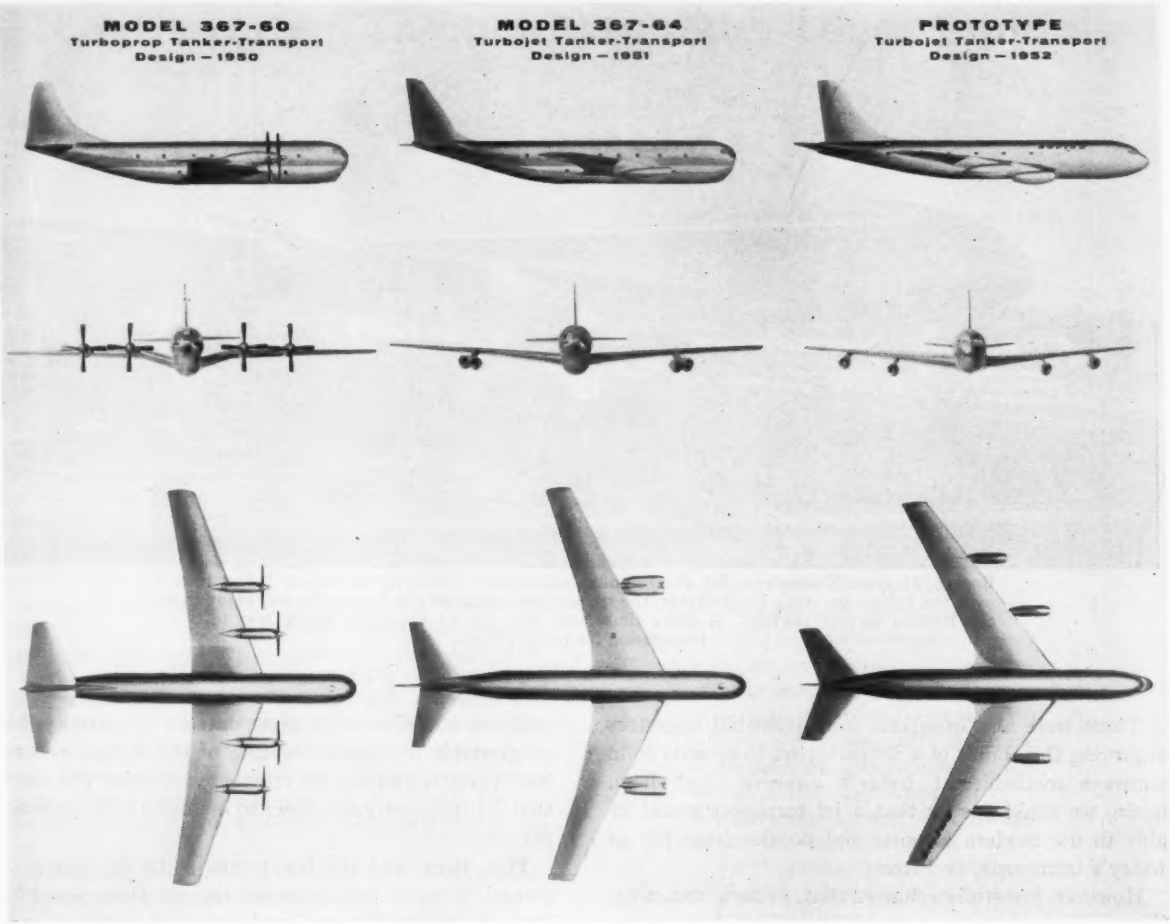
Still another advantage is the fire protection afforded by isolating the jet engine in a pod below the wing. With such an arrangement, there is little danger of any fire in an engine spreading to the rest of the airplane. Pod-mounting of power plants could be practical only with jet engines, which have no propellers to consider.

Even the fuel used for jet engines would be a safety advantage, since its use, like the use of engine pods, minimizes the threat of fire.

Now we come to reliability. Two factors are important here, and of these the most important undoubtedly is simplicity. The jet airplane could be fundamentally simpler than earlier types, we determined, and its reliability should improve in direct proportion. Experience is the second factor in reliability. This comes only with prolonged use of a particular unit. Military use of jet airplanes is making such experience available; and components suitable for use in a jet transport would be thoroughly tried and proved before jet transports are available in production quantities.

I have mentioned the long months of engineering research that went into the evolution of the present Boeing jet tanker-transport prototype. It should be mentioned here, again, that that engineering research included trips in which information on the latest Boeing jet transport design study was traded, so to speak, for information on the demands of transport operators, both military and commercial.

We found that among potential customers there was a question as to whether a jet transport could fit itself

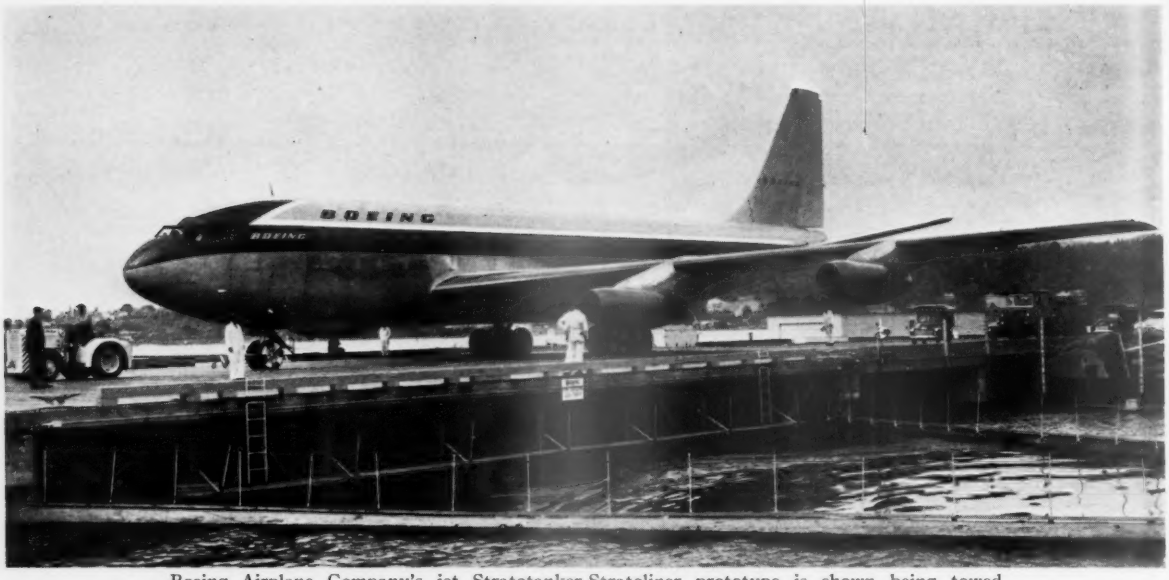


into the present traffic patterns of other airplanes that would be using the airports. By the time our jet tanker-transport design was developed, we could answer in the affirmative: although the jet transport would climb at an unusually high rate and at a higher speed than conventional transports, it could conform exactly to the present speeds and angles of climb at a small sacrifice in efficiency. Similarly, the descent and approach to the airport could be exactly like that of a present-day transport through the use of special drag-producing devices that are now well developed.

Potential customers were also interested in what the flight deck or cockpit would be like. We were able to tell them that a conventional cockpit could be built into a jet transport; and, later, work on the actual prototype showed we could comply with all the basic recommendations of the S.A.E. cockpit standardization committee, which appear to give nearly ideal cockpit arrangement. This later detail work on the prototype design also emphasized the simplicity of the jet transport's cockpit. For instance, to control its power plants, a present-day four-engined transport has—in addition to four throttles—four mixture controls, four propeller pitch controls, four propeller feathering buttons, four cowl flap controls, four oil cooler controls, and possibly four supercharger controls and four intercooler controls. The jet transport has four throttles only.

It is not often that designers of a new type of airplane can decrease complexity while increasing performance.

America's first jet transport, the new Boeing prototype, is shown here in this first released photo as it neared completion by Boeing Airplane Company at Renton, Wash. It represents a private investment by Boeing Airplane Company of more than $15,000,000. This new "transport of the future" is 128 ft. long, its wings measure 130 ft. from tip to tip, and it will weigh 190,000 lbs. in fully loaded condition. Cruising speed is in the 550 m.p.h. class.



Boeing Airplane Company's jet Stratotanker-Stratoliner prototype is shown being towed over the bridge spanning Cedar River, the stream that separates the Boeing Renton plant from the Renton Airport runway. A short time later, the big jet transport began taxi tests in preparation for its first flight.

There were also questions from potential operators regarding the ability of a jet transport to operate from runways available at today's airports. But here, again, we could answer that a jet transport would be able to use modern airports and do the same job as today's transports, or better.

However, our studies showed that, in some instances, if it was desired to operate the jet transport over greater distances than today's transports are capable of flying, greater field lengths could be used. This was considered no disadvantage, since even with longer runways today's aircraft could not do a similar job.

Another question was what type of landing gear should be used. Our bombers use a bicycle gear in order to house the main gear in the body and still reserve the space near the center of gravity for the bomb bay. With the transport, it became possible to develop a more conventional tricycle gear that would permit ground-handling characteristics similar to those of today's transports. This was achieved by designing the main gear so that it retracted sideways into the body aft of the wing.

Maintenance is so important a factor in air transport operation that it was decided to conduct a complete review of operational experience with present airplanes in order to establish standards for a future transport. Many trips were taken to bases of Military Air Transport Service and other Air Force units and to various air-line operating bases. On the basis of our review, we were able to establish certain goals in terms of equipment accessibility, removability, and so forth. Early studies indicated that such goals could be realized. Our experience in the design of the prototype appears to have verified these predictions. Much of the credit for achievement of an early flight date on the prototype is attributable to this one feature of the design, and we have every confidence that further experience will prove that jet transports are easier to maintain than past airplanes.

This, then, was the background. In the course of several years we had answered the questions posed by Boeing's engineering staff and potential operators with regard to design and performance factors, operations, reliability, and maintenance. An examination of our findings led us in early 1952 to conclude that the time to start development of a jet tanker-transport airplane was *now*.

Since then, there has been plenty of work to do, much planning to carry out, a good number of problems to solve—but, most important of all to our success, enormous teamwork and a high level of enthusiasm within our organization.

Because of our firm desire to keep the airplane as simple as possible and an early resolution to stick to the use of proved components and known processes as much as possible, we have had better than average success in making things work the first time.

Of course, we have had a few bad moments along the way, but we have never had cause to question the basic wisdom of the decision to proceed with the design and development of a jet transport.

We believe we have created in this prototype the airplane that will usher in a new age in the transportation of men and materiel. Our wish is that it may contribute substantially to the increased well-being of our country and the world, both indirectly through strengthening a vital part of our defense system and directly by providing an essential tool for the building of an even better system of air transportation.

Laminarization Through Boundary-Layer Control*

G. V. LACHMANN†
Handley Page, Ltd.

SUMMARY

The essential prerequisite for laminarized aircraft is a surface finish that is compatible with the maintenance of a laminar boundary layer thinned down by suction.

Analysis of the effect of isolated roughness on transition which needs experimental corroboration suggests that the height of isolated surface excrescences should be well below 50 per cent of the local displacement thickness of the boundary layer where suction is applied.

Distributed suction is the ideal solution from an aerodynamic point of view since it avoids localized reduction of boundary-layer thickness due to suction, but it is the most difficult method in practice.

Closely spaced rows of spanwise sinks offer the best compromise.

The aerodynamic design should take into account the existence of two critical limits for the boundary-layer thickness with applied suction. The upper limit is best defined by a critical value of $R\vartheta$ for which a conservative value is $R\vartheta_{crit.} = 1{,}250$. The ratio of the critical values of momentum thickness (with maximum and minimum suction) $\leqq 1$ is proportional to a Reynolds Number formed with roughness height as length and a constant.

Care without unduly great practical difficulties in production and maintenance should make possible flight with laminar boundary layer, stabilized by suction, at values of U/ν of the order $1.5 \div 3 \times 10^6$.

Cruising in the stratosphere at such values of U/ν makes possible the attainment of high subsonic Mach Numbers.

The benefits resulting from drag reduction due to laminarization demand a proper choice of cruising height to achieve optimum flight speed combined with a power plant tailored to supply the required cruising thrust.

The resulting power plant may produce insufficient take-off thrust, and highly laminarized aircraft will need some form of take-off assistance or novel methods of take-off altogether.

Secondary improvements of performance will result from the possibility of employing substantially reduced power plants, and from improvements of propulsive efficiency if laminarization is extensive enough to justify boundary-layer propulsion.

Designers everywhere in the world realize that they stand on the threshold of radically new developments in the field of military aviation where the urge toward the attainment of high supersonic Mach Numbers is all-powerful and overshadows considerations of flight economy.

The engineering problems bound up with the realization of flight at high supersonic speed over long distances are probably vastly greater than those involved by laminarization. However, nobody seems to doubt that they can and eventually will be mastered, because it is a military necessity that they should be overcome.

However the prediction is ventured that the bulk of passenger carrying or transport aircraft will stay subsonic for a long time to come.

Laminarization remains the only fundamental aerodynamic possibility to improve the economy of flight in the subsonic regime.

NOMENCLATURE

a	=	speed of sound
c	=	wing chord
H	=	flight altitude
l	=	distance between suction strips
M	=	flight Mach Number
Q	=	sucked volume per unit span
s	=	downwind width of suction strip
u	=	velocity at a point in the boundary layer
U	=	velocity just outside boundary layer
U_0	=	flight velocity
v	=	inflow velocity at a strip
x	=	distance downstream from leading edge
x_0	=	distance to transition with no roughness
x_T	=	distance to transition on rough surface
x_ϵ	=	distance to a roughness element
x_ζ	=	an arbitrary distance from leading edge
ϵ	=	height of a roughness element
ϑ	=	boundary layer momentum thickness
$\vartheta_{crit.}$	=	transition momentum thickness (upper limit)
ν	=	kinematic viscosity
δ^*	=	boundary layer displacement thickness
$\delta_{crit.}{}^*$	=	$\delta_{T_u}{}^*$
$\delta_0{}^*$	=	transition displacement thickness (no roughness)
$\delta_{T_u}{}^*$	=	transition displacement thickness (upper limit)
$\delta_{T_l}{}^*$	=	transition displacement thickness (lower limit)
$\delta_\epsilon{}^*$	=	displacement thickness at roughness element
$\delta_\zeta{}^*$	=	displacement thickness at x_ζ
C_Q	=	$\dfrac{Q}{U \cdot s} = \dfrac{v}{U}$ = suction coefficient based on strip width
C_{Q_n}	=	$\dfrac{Q_n}{U_0 \cdot c}$ = suction coefficient of nth strip based on chord length
R	=	Re = Reynolds Number
R_c	=	$\dfrac{U_0 c}{\nu}$
R_{x_0}	=	$\dfrac{U_0 \cdot x_0}{\nu}$
R_{x_T}	=	$\dfrac{U_0 \cdot x_T}{\nu}$
$R\delta_{crit.*}$	=	$\dfrac{U_0 \cdot \delta_{crit.*}}{\nu}$
$R\vartheta_{crit.}$	=	$\dfrac{U_0 \cdot \vartheta_{crit.}}{\nu}$
$\left(\dfrac{U}{U_0}\right)_n$	=	local velocity ratio at the nth strip
$\dfrac{U}{U_0}$	=	local velocity ratio
t/c	=	wing thickness-chord ratio
ϑ/c	=	momentum thickness/chord ratio
$(\vartheta/c)_n$	=	momentum thickness/chord ratio just before the nth strip

* The author gratefully acknowledges the great measure of assistance he received from J. B. Edwards (Aerodynamics Dept., Handley Page, Ltd.) in the preparation of this paper, especially in respect to the development of methods and in clearing up several fundamental aspects of the problems discussed.

Permission by the Ministry of Supply to publish Figs. 2 and 3 is also acknowledged with thanks, also the permission by Handley Page, Ltd., to publish this paper.

† Director of Research.

$\left(\frac{\vartheta'}{c}\right)_n$ = momentum thickness/chord ratio just after the nth strip

Introduction

Boundary-layer control can be applied either for the purpose of preventing separation of flow at large angles of incidence or for the purpose of stabilizing the laminar boundary layer.

This paper is devoted only to the latter form of boundary-layer control.

It is, of course, possible to apply both forms of boundary layer control on the same aircraft using the same pump aggregate.

The coefficient of total drag minus induced drag referred to the total wetted surface is, for well-designed modern subsonic aircraft, of the order of the friction coefficient for a flat plate with fully developed turbulent boundary-layer, of equivalent mean Reynolds Number.

A great deal of theoretical research has been devoted during the past decade or so to the problem of stabilizing a laminar boundary layer in the presence of an adverse pressure gradient, especially in Great Britain, Germany, the United States, and Switzerland. Wind-tunnel tests and experiments in flight have confirmed theoretical findings. A number of the most important contributions are given in the bibliography.

It can be shown that by judicious design and choice of cruising altitude and thrust substantial performance improvements are possible, at least within the subsonic range of flight in the stratosphere, and that the engineering difficulties are not insurmountable. Defining correctly and accurately these technical requirements is the task of research; prediction of impracticability discourages and delays progress.

Once designers and aircraft constructors had clearly appreciated both the potential advantage and the exact technical requirements, many dogmas were disproved in the course of the development of aviation.

PART I

Unit Reynolds Number U/ν as the Essential Criterion for Boundary-Layer Suction

When interpreting results obtained with boundary-layer suction on small chord models in a pressurized wind tunnel chord Reynolds Number is rather a misleading basis of comparison, bound to evoke an unjustified degree of pessimism in the minds of aircraft designers.

It has been observed that the stability of the laminar boundary layer at chord Reynolds Numbers of the order of those occurring in flight was extremely sensitive to surface conditions of the small chord model. A degree of surface finish was found to be necessary, difficult, if not impossible, to achieve on actual aircraft wings.

For reasons of geometric similarity the ratio ϵ/c has to be the same for wing and model at the same chord Reynolds Number. The permissible height of a surface excrescence is expressed by ϵ, and c equals wing chord.

Assuming a critical value R_{δ^*} at a certain position x/c of the chord of the wing with a certain method of boundary-layer suction, the local displacement thickness at x will be $\delta_1^* = R_{\delta^*}/U/\nu$. There will be a critical value ϵ/δ^* which, when exceeded, will cause transition. It follows that

$$\epsilon = R_{\delta^*}/U/\nu = R_{\delta^*} \cdot c/R_c \qquad \text{or} \qquad \epsilon/c = R_{\delta^*}/R_c$$

The following conclusions can thus be drawn:

(1) If the ratio R_{δ^*}/R_c is constant, permissible values of ϵ vary in the same ratio as the chords of model and wing. Actually, however, the value of R_{δ^*} may be higher in free atmosphere due to reduced turbulence than in the tunnel, and hence the ratio $(\epsilon/c)_{\text{wing}}$ may be greater than for a wind-tunnel model.

(2) For a given type and size of roughness and a given value of R_{δ^*} the critical value of U/ν may be constant.

In support of this statement the observation is made that increase of R_c with a certain type of suction (Langley Field tests) was in direct proportion to wing chord.

(3) It also follows that R_{δ^*} is greater for distributed suction, compared with suction through spanwise sinks arranged at chordwise intervals if, with the same model chord, and probably the same degree of surface roughness, greater values of R_c are obtained. (*Example:* Model tests by Braslow and Visconti.[35])

While it is obvious that chord is meaningless for the case of distributed suction, the same applies to a wing where suction is applied through discrete strips of porous material or slots. Such a wing of indefinite chord is best defined in terms of strip spacing l, the width s of a strip, and the measure ϵ of the roughness of the surface.

Supposing that at a given speed U, laminar flow can be obtained with suction velocity v through the porous surface, then the suction quantity per strip is $Q = v \times s$ and a coefficient may be defined as $C_Q = Q/s \cdot U = v/U$.

Neglecting possible turbulence and compressibility effects, the principles of dynamic similarity show that for any wings that are similar to each other and for which the ratios s/l and ϵ/l are unchanged, the flow will be similar and in particular laminar, provided the parameters $U \cdot l/\nu$ and v/U are the same.

It immediately follows that C_Q per strip (as defined) is unaltered. It may be shown that R_{δ^*} measured just in front of each strip is determined by the values of $U \cdot l/\nu$ and C_Q and is, therefore, the same in both cases.

For a given standard of construction, surface roughness ϵ remains the same, and for similarity, the strip spacing and width must be kept constant, though the chord may be increased. In other words, for a given value U/ν any chord Reynolds Number can be obtained.

It also follows that laminar flow may be obtained at higher speeds provided the kinematic viscosity, and therefore the altitude of flight, is increased accordingly.

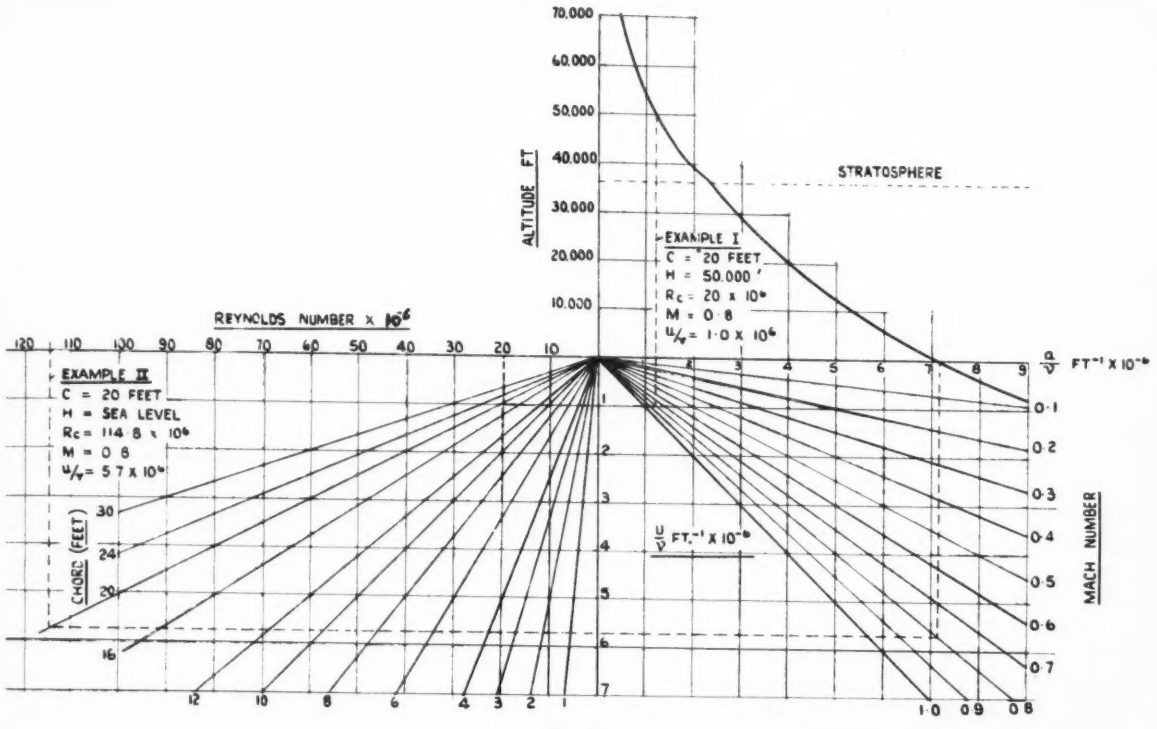


FIG. 1.

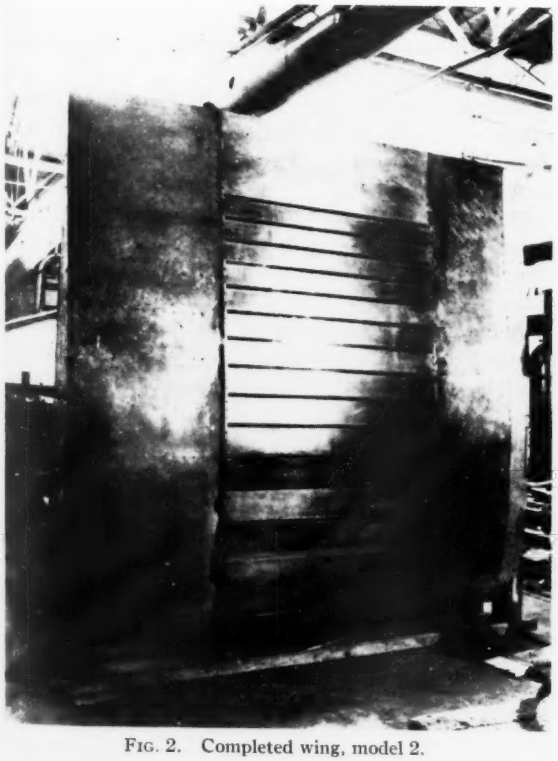


FIG. 2. Completed wing, model 2.

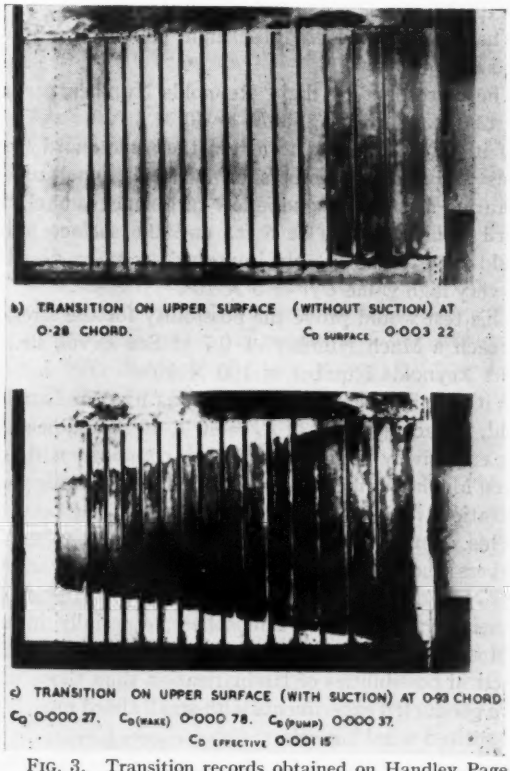

b) TRANSITION ON UPPER SURFACE (WITHOUT SUCTION) AT 0·28 CHORD.
$C_{D\ SURFACE}$ 0·003 22
c) TRANSITION ON UPPER SURFACE (WITH SUCTION) AT 0·93 CHORD
C_D 0·000 27. $C_{D(WAKE)}$ 0·000 78. $C_{D(PUMP)}$ 0·000 37.
$C_{D\ EFFECTIVE}$ 0·001 15

FIG. 3. Transition records obtained on Handley Page wing. Incidence 0°, wind speed 180 ft. per sec., Reynolds Number $R_c = 9.2 \times 10^6$.

This statement is strictly correct only while applied to a surface having spanwise sinks arranged at constant distances l, with ϵ/l = constant, and where the pressure gradient $\Delta p/l$ is constant. $R = U \cdot l/\nu$ is obviously the only significant criterion, and any chord Reynolds Number R_c can be reached provided R_l is constant.

Let us consider two airfoils at the same value of U/ν, both having the same standards of surface finish expressed by ϵ and the same strip spacing.

The large airfoil will have a greater number of strips and the pressure gradient $dp/dx = f(x/c)$ will be less than for the smaller airfoil.

Therefore, if a given strip spacing l is found satisfactory on the airfoil of smaller chord, it will certainly be satisfactory for a larger airfoil at the same value of U/ν, and the large airfoil will, of course, operate at a greater chord Reynolds Number.

The increase of speed with altitude at constant values U/ν is considerable. A wing that is found satisfactory at a speed $U = 200$ ft. per sec. at Sea Level should be equally satisfactory at 800 ft. per sec. at 45,000 ft., provided there are no compressibility effects.

As an illustration, values for U/ν are plotted over flight Mach Number M as function of altitude H (Fig. 1). This figure shows the interrelation between flight Reynolds Number, chord, Mach Number M, U/ν, a/ν, and height. The type of airfoil, especially the t/c ratio, fixes the Mach Number. Let us assume $M = 0.7$ and $U/\nu = 2 \times 10^6$, a value that does not make too exacting demands on surface finish.

The height at which these flight conditions are fulfilled is $H = 30{,}000$ ft.

The corresponding flight Reynolds Number, assuming a 20-ft. chord wing, is $R_c = 40 \times 10^6$.

If it were attempted to attain the same chord Reynolds and Mach Numbers on a wind-tunnel model operating in an atmospheric low turbulence tunnel, the chord would have to be 8 ft., and the surface finish would have to be greatly improved to make possible the very high value $U/\nu = 5 \times 10^6$.

This test would prove the possibility for the aircraft to reach a Mach Number of 0.7 at Sea Level, i.e., a flight Reynolds Number of 100×10^6.

With similar chords (3 to 4 ft.) as used in Langley Field, the achievement of $R_c = 40 \times 10^6$ would necessitate excessively large values of U/ν combined with reduced Mach Numbers ($M = 0.2$) and considerable pressurization, i.e., simulation of flight below Sea Level.

This comparison may explain why those research workers who have studied laminar boundary layer flow on large chord models in atmospheric low-turbulence tunnels, or in the free atmosphere, especially in the stratosphere, are considerably more optimistic about the practical possibilities of laminarization than those who have conducted experiments with small chord models in pressurized wind tunnels.

Fig. 2 shows an early model in realistic construction of 8-ft. chord.

Fig. 3 shows observed transition (China clay method) at a value of $U/\nu = 1.15 \times 10^6$. (Actually values of $U/\nu \sim 2 \times 10^6$ with laminar flow to 0.93 chord were obtained with this model.)

PART II

The Mechanism of Laminarization and Design of Suction Surfaces

In order to get a qualitative appraisal of the mechanism of laminarization and in order to define the essential design parameters, let us consider suction through two porous strips a_1 and a_2 separated in chordwise direction by distance l (Fig. 4).

The zig-zag line b represents the change of thickness of the stable boundary layer. Reduction of boundary-layer thickness occurs while boundary layer is withdrawn through the spanwise sinks (negligible sink effect is assumed), followed by a build-up of thickness during the passage from one strip to the next. Upper and lower limits of the stable range are marked by $\delta_{Tu}{}^*$ (upper limit) and $\delta_{Tl}{}^*$ (lower limit). $\delta_{Tu}{}^*$ is determined by stability considerations (Tollmien-Schichting type instability), and the lower limit $\delta_{Tl}{}^*$ by transition due to surface roughness.

Dotted lines b' and b'' indicate the effect of either undersucking or oversucking.

Oversucking leads to transition due to the roughness effects and insufficient suction leads to instability.

It is obvious that closing up the distance of strips (reduction of l) ensures stability with reduced local suction and less reduction of boundary-layer thickness.

Hence, relatively greater surface roughness becomes tolerable for the same value of U/ν. If the strip spacing is reduced more and more, eventually the case of distributed suction is attained.

According to the above, one should expect higher values of U/ν for stable flow with distributed suction than for strip suction, surface roughness being the same in both cases.

This seems to be confirmed by the experiments of Braslow and Visconti[35] with a model of 64A 010 airfoil having a porous bronze skin where the remarkably high value of $U/\nu = 5 \times 10^6$ was measured.

On examining boundary-layer profile and thickness at the upstream and downstream edges of a suction strip, it will be found that Profile I approaches more and more

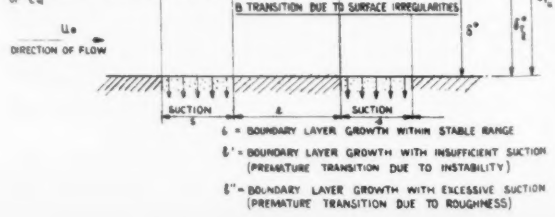
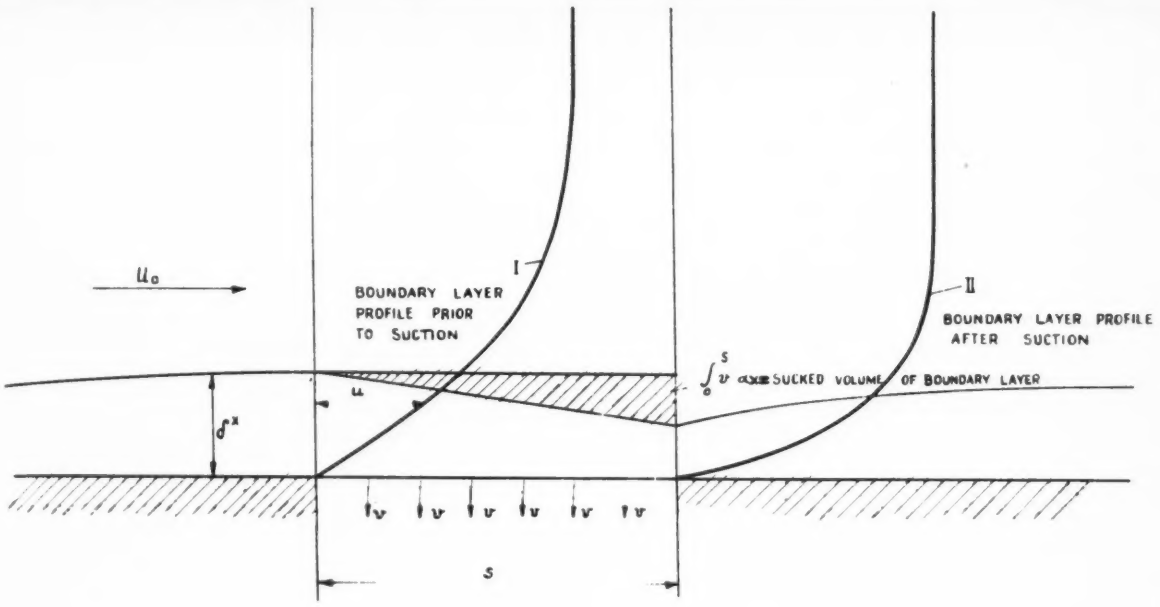

A TRANSITION DUE TO INSTABILITY
STABLE PRACT. RANGE WITH MARGIN FOR SMALL VARIATIONS OF C.Q
B TRANSITION DUE TO SURFACE IRREGULARITIES
DIRECTION OF FLOW
SUCTION
SUCTION
δ = BOUNDARY LAYER GROWTH WITHIN STABLE RANGE
δ' = BOUNDARY LAYER GROWTH WITH INSUFFICIENT SUCTION (PREMATURE TRANSITION DUE TO INSTABILITY)
δ'' = BOUNDARY LAYER GROWTH WITH EXCESSIVE SUCTION (PREMATURE TRANSITION DUE TO ROUGHNESS)

FIG. 4.



CHANGE OF BOUNDARY LAYER THICKNESS AND PROFILE DUE TO SUCTION

FIG. 5.

the ordinary Blasius type as distance l between strips widens, while the Profile II will be generally found more convex and almost identical with the profile of an asymptotic boundary layer (Fig. 5).

Reducing strip distance results in improvements at both ends of the range, Profile I approaching the more stable shape of Profile II, and boundary-layer thickness becoming more evenly distributed.

According to Fig. 4 a narrow range of stable laminar flow is possible between an upper and a lower limit.

The upper limit could be defined by a critical value of $(R_{\delta^*})_{crit.}$.

Comparison of $(R_{\delta^*})_{crit.}$ for a wing with suction applied through spanwise sinks and for one without suction but having a zone of laminar flow due to favorable pressure gradient showed reasonably good agreement, but the agreement between the values of $(R_\vartheta)_{crit.}$ (Reynolds Number based on momentum thickness) was much closer.

A conservative value for $(R_\vartheta)_{crit.}$ based on wind-tunnel experiments is $(R_\vartheta)_{crit.} = 1{,}250$ (including roughness effect).

Design of Suction Surfaces

The growth of the relative momentum thickness ϑ/c between two discrete suction sinks n and $n+1$ is shown in Fig. 6. The relative momentum thickness before suction is applied is represented by $(\vartheta/c)_n$ while $(\vartheta/c)_n'$ is the value after the thickness has been reduced by suction.

Expressions for the ratio $\left(\frac{\vartheta}{c}\right)_n' \Big/ \left(\frac{\vartheta}{c}\right)_n$ and for the rate of growth between two adjacent sinks are given in the Appendix.

The critical value for $(\vartheta/c)_n$ (upper limit) depends on the value $(R_\vartheta)_{crit.}$, the chord Reynolds Number R_c, and the local velocity ratio $(U/U_0)_n$. It also depends on the degree of surface roughness, as will be shown later, on the spacing of sinks, and on the degree of turbulence in the free atmosphere.

A relationship between the suction coefficient $C_{Q_n} = Q/U \cdot c$ and the ratio $(\vartheta'/\vartheta)_n$ can be derived by assuming that the boundary-layer profile II (after suction) obtains from the profile I (prior to suction) by cutting off the lower tip of Profile I (Fig. 7).

Design procedure is as follows:

Starting from the leading edge, growth of ϑ/c with x/c is calculated for the unsucked boundary layer.

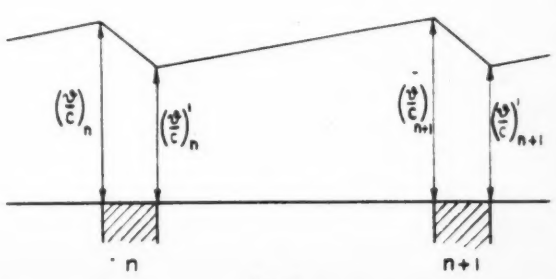


FIG. 6.

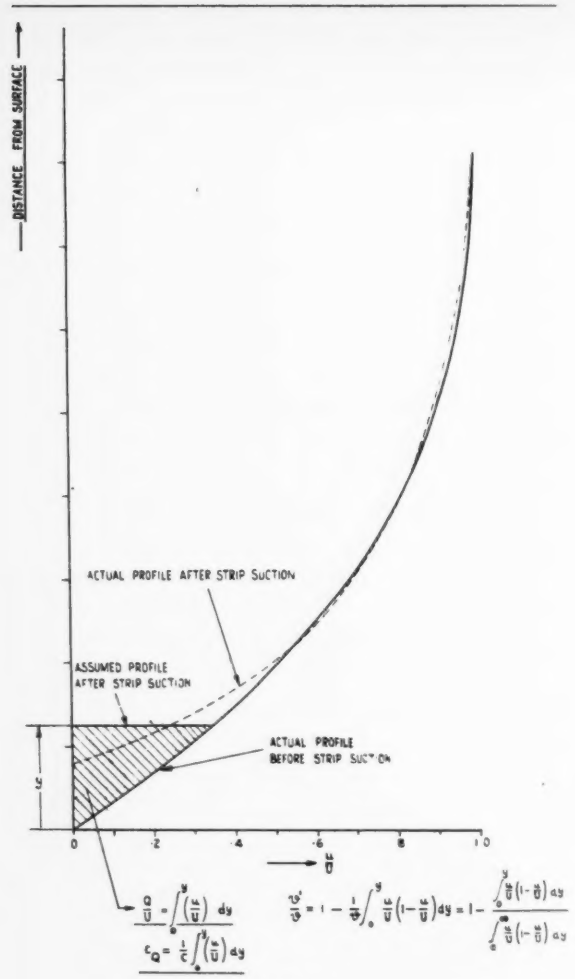


FIG. 7.

A curve is drawn which represents the critical value of ϑ/c along the chord according to the local values of U/U_0.

When, or preferably before, the boundary-layer growth curve approaches the top limit of ϑ/c the first spanwise sink must be arranged (Fig. 8).

Suction is now applied through the sink until a permissible lower value for (ϑ/c) is approached. Thus, the local value of c_Q is determined since

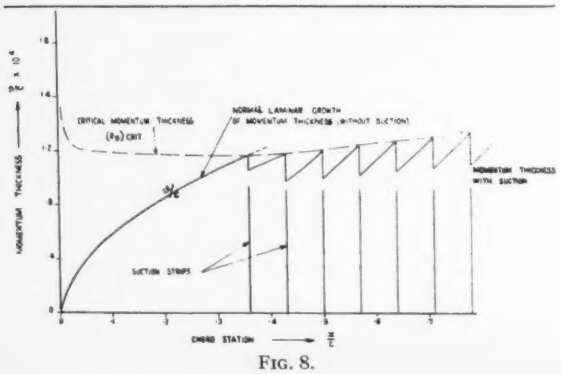


FIG. 8.

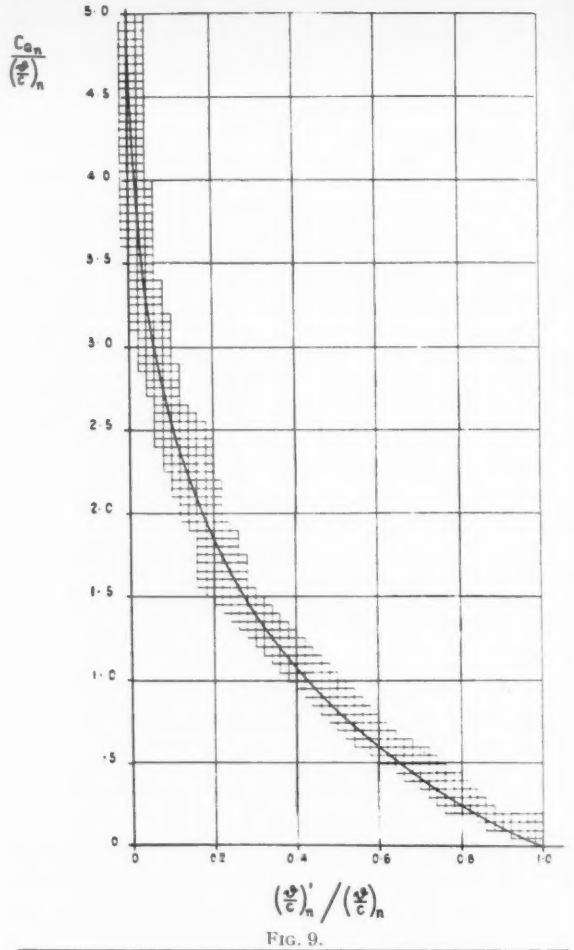


FIG. 9.

$$\frac{(\vartheta/c)'}{(\vartheta/c)} = \frac{f(c_Q)}{(\vartheta/c)} \qquad \text{(Fig. 9)}$$

Starting from the new value $(\vartheta/c)'$ the calculation of the boundary-layer growth is repeated in the same manner until the growth curve approaches again a critical value of ϑ/c.

This process continues until the trailing edge is reached.

The method has given reasonably good agreement with experimental observations as indicated in Fig. 10.

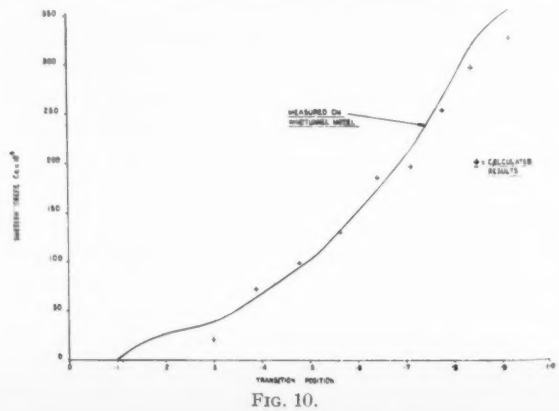


FIG. 10.

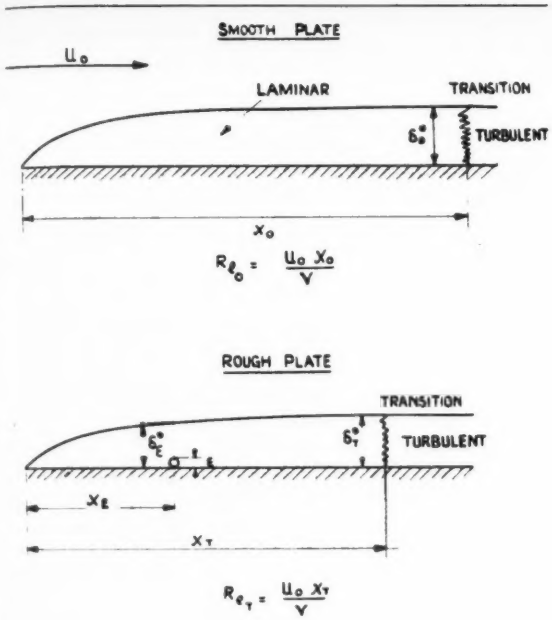


FIG. 11.

PART III

EFFECT OF SURFACE ROUGHNESS ON TRANSITION

Both upper and lower limits of the boundary-layer thickness are critically affected by surface roughness or by a kind of virtual roughness when suction is applied through perforations in the skin. The exact physical nature of this phenomenon is not yet fully explored, but experiments with perforations have indicated that the pitch/diameter ratio of the holes in spanwise and chordwise direction are critical parameters, also the chordwise distribution of rows of holes.

It has been known for some time that a roughness element of subcritical height can move transition forward, i.e., toward the leading edge, without necessarily bringing it right up to the element itself. In other words, there is a kind of "infectious" transition and a type that might be termed "catastrophic" transition.

The two different types of transition were first disclosed by Fage's[38] experiments with roughness elements of various shapes in an airflow with favorable pressure gradient.

The Tollmien-Schlichting theory of boundary-layer stability supports this observation. The roughness element adds a further disturbance to those already present from the initial turbulence of the flow. Transition will occur earlier on a rough surface since with a larger disturbance less amplification is required.

A recent analysis by Dryden,[42] chiefly of Japanese experiments by Tani, Hama, and Mituisi,[43] offers a good and transparent basis for estimating the effect of roughness on a boundary layer, especially a boundary layer with reduced thickness due to suction.

Dryden found that if the following three nondimensional parameters were selected, i.e., transition Reynolds Number R_{ET}, the relative height $\epsilon/\delta_\epsilon^*$ of the roughness element, and the location parameter x_ϵ/ϵ, the experimental data could be well represented by a single curve of R_{ET} vs. $\epsilon/\delta_\epsilon^*$ so long as the resulting $x_T < x_\epsilon$ (Fig. 11).

He finally derived a curve for the relationship between the ratio of transition Reynolds Number R_{ET} with and without roughness on a flat plate and the ratio of local roughness height ϵ to the local displacement thickness δ_ϵ^* (Fig. 12).

The curve is applicable for values of ϵ up to the "catastrophic" value where transition catches up to the roughness element, i.e., where $x_E = x_T$. Further in-

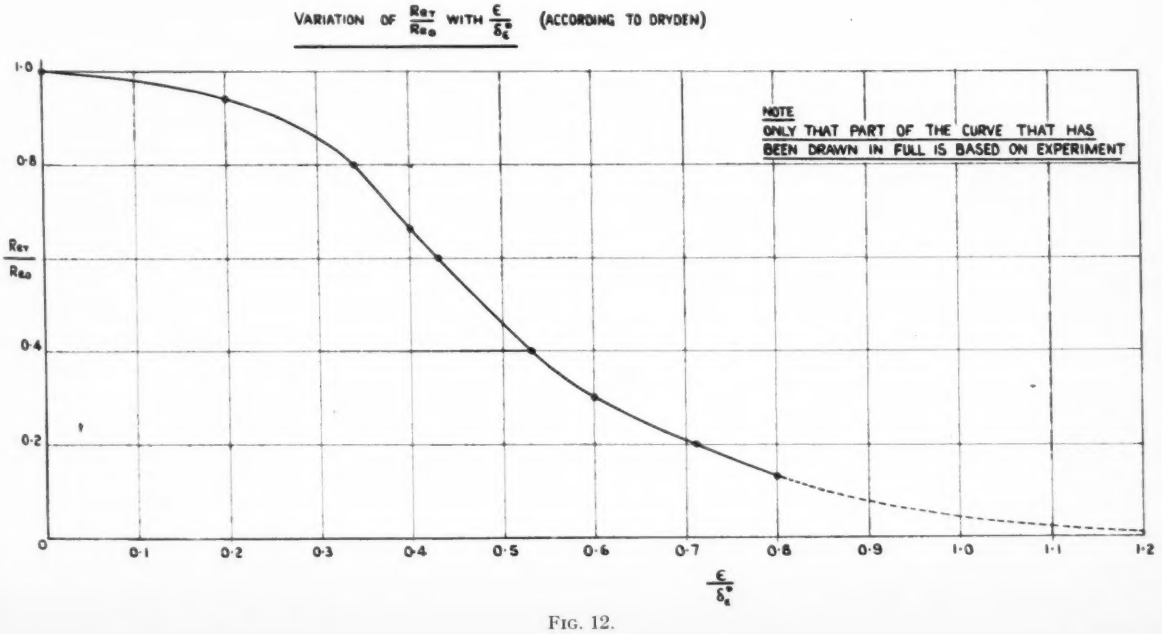


FIG. 12.

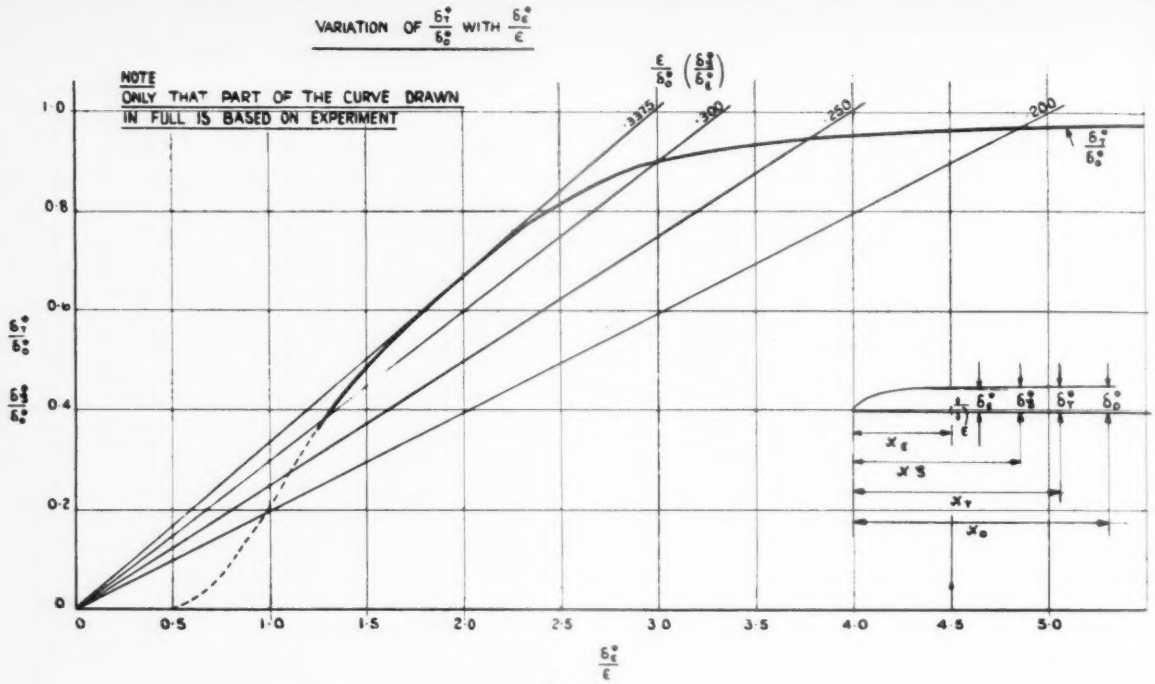


FIG. 13.

crease of magnitude of ϵ does not affect the position of transition.

When considering conditions in the boundary layer of an airfoil with pressure gradient, the displacement thickness δ^* is a more suitable criterion than R_{ET}.

Since

$$\frac{\delta_T^*}{\delta_0^*} = \sqrt{\frac{R_{et}}{R_{e_0}}}$$

for a laminar boundary layer, Dryden's diagram can be redrawn as shown in Fig. 13.

In this diagram lines for constant values of

$$\frac{\delta_T^*}{\delta_0^*} = \left(\frac{\delta_\epsilon^*}{\epsilon}\right)\frac{\epsilon}{\delta_\epsilon^*}\left(\frac{\delta_\zeta^*}{\delta_\epsilon^*}\right)$$

are drawn with

$$\frac{\epsilon}{\delta_0^*}\left(\frac{\delta_\zeta^*}{\delta_\epsilon^*}\right)$$

as parameter.

Where

δ_ζ^* = displacement thickness at point x_ζ
δ_ϵ^* = displacement thickness at point x_ϵ

At the intersection of these lines with the curve δ_T^*/δ_0^* values for δ_ζ^* equal those for δ_T^*, and thus transition occurs at x_ζ.

It follows from Fig. 13 that there are three characteristic regimes, which we will denote A, B, and C. An illustration is given in Fig. 14. Here a roughness element is gradually moved upstream from a downstream position of natural transition, i.e., the point where transition takes place for the smooth surface. As the roughness element moves upstream away from the natural transition position, transition moves with the element. This is Regime A.

Presently, transition begins to lag behind the roughness element (Regime B), but finally transition catches up again with the roughness element, and the two move together again (Regime C).

A useful graph is obtained from Diagram 13 letting ζ become the locus of transition and $\delta_\zeta^* = \delta_T^*$.

In Fig. 15 δ_T^*/δ_0^* is plotted over ϵ/δ_0^* $(\delta_T^*/\delta_\epsilon^*)$.

Since $\delta_T^*/\delta_\epsilon^* = 1$ when transition reaches the roughness element, the following values can be derived

$$X = \left(\frac{\epsilon}{\delta_0^*}\right)_{max.} = 0.3373$$

$$\psi = \left(\frac{\delta_T^*}{\delta_0^*}\right)_{max.} = 0.676$$

From this follows

$$\left(\frac{\epsilon}{\delta_T^*}\right)_{max.} = \left(\frac{\epsilon}{\delta_\epsilon^*}\right)_{max.} = \frac{X}{\psi} = 0.5$$

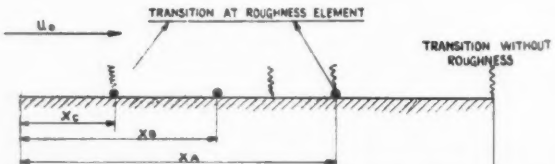


FIG. 14.

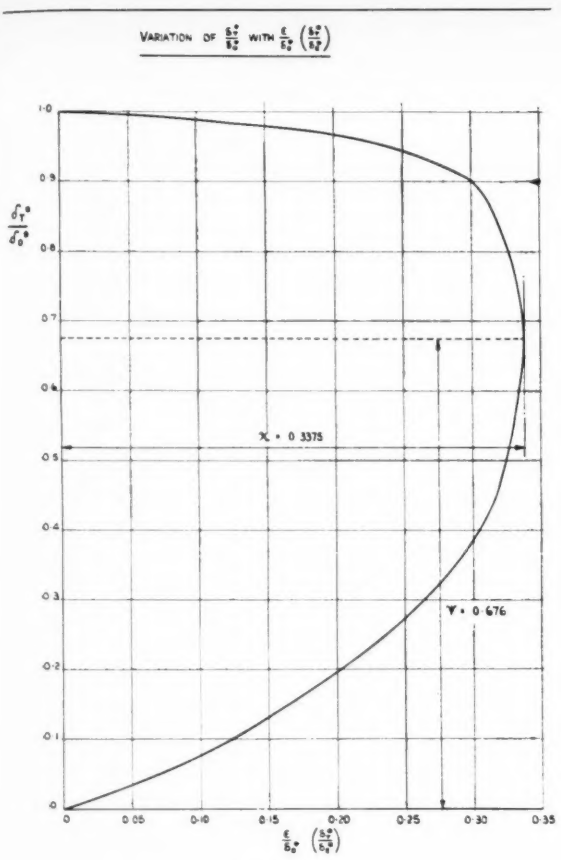


FIG. 15.

In other words, the height of an isolated roughness should be less than one half the displacement thickness of the boundary layer to avoid catastrophic transition at the roughness element.

In Fig. 16

$$\delta_T^* = \delta_\epsilon^* = 2\epsilon_{max.} = \psi \frac{R\delta_0^*}{\left(\frac{U}{U_0}\right)\left(\frac{U_0}{\nu}\right)}$$

is plotted over $(U/U_0)\ U_0/\nu$ with $R_\delta^* = 3{,}000$, 4,500, and 6,000 as parameter.

The actual value of R_δ^* at any position of the airfoil contour depends on the local pressure gradient and form parameter to be evaluated by methods suggested by Pohlhausen, Schlichting, Thwaites, and others, and also on the degree of turbulence in the atmosphere.

It has been observed on airfoils to which boundary-layer suction was applied, both in the course of wind-tunnel or free-flight experiments, that either under- or oversucking can lead to transition.

This observation confirms that for a given surface finish or roughness height ϵ there are two limits for δ_T^* within which laminar flow is possible.

The upper limit $\delta_{T_u}^*$ indicates the case with least amount of suction, and the lower limit $\delta_{T_l}^*$ corresponds to the case with maximum suction.

For the case of suction through discrete sinks, there must be a certain range available for δ_T^* within which the flow remains laminar. It is obvious that in this case $(\delta_{T_l}^*/\delta_{T_u}^*) < 1$ and that the tolerable height of roughness ϵ must be smaller, at a given value of U/ν, than with distributed suction.

As an illustration, the variation of $\delta_{T_l}^*/\delta_{T_u}^*$ with ϵ and $(U/U_0)U_0/\nu$ assuming a critical value $R\delta_0^* = 4{,}500$ has been plotted in Fig. 17.

EFFECT OF SURFACE ROUGHNESS ON THE DESIGN OF A SUCTION SURFACE

Considering the case of a single suction strip, displacement thickness of the boundary layer just before suction is applied may be δ_u^* and δ_l^* after suction has been applied.

If transition is imminent $\delta_u^* = \delta_T^*$.

It follows from Fig. 15 that the ratio

$$\frac{\delta_T^*}{\delta_0^*} = \frac{\delta_0^*}{R_{\delta_0}^*}\left(\frac{U}{\nu}\right) = 0.676$$

gives the maximum value for

$$\frac{\epsilon}{\delta_0^*} = \frac{\delta_T^*}{\delta_\epsilon^*} = \frac{\epsilon}{R_{\delta_0}^*}\left(\frac{U}{\nu}\right)\frac{\delta_u^*}{\delta_l^*} = 0.338$$

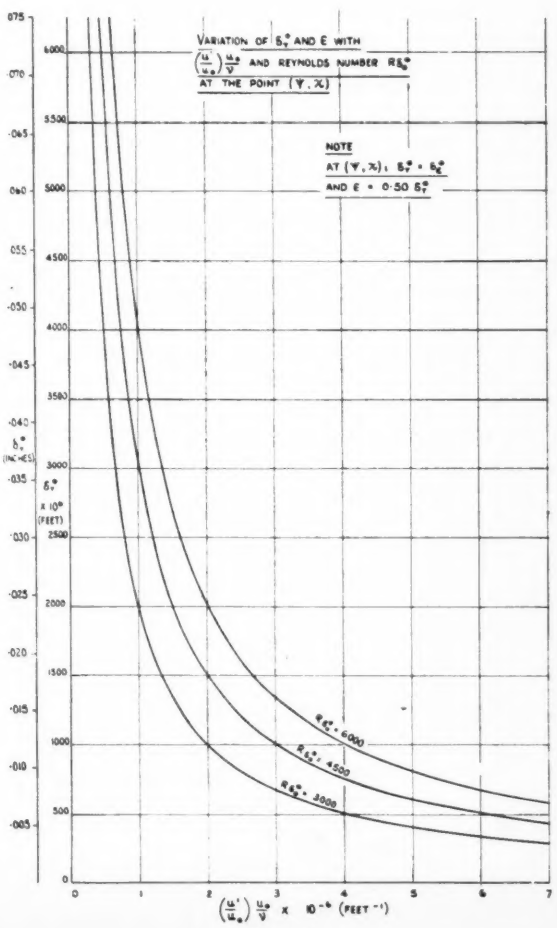

VARIATION OF δ_ϵ^* AND ϵ WITH $\left(\frac{u'}{u_e}\right)\frac{u_0}{\nu}$ AND REYNOLDS NUMBER $R\delta_0^*$ AT THE POINT (Y, X)
NOTE
AT (Y, X), $\delta_\epsilon^* = \delta_\epsilon^*$ AND $\epsilon = 0{\cdot}50\ \delta_\epsilon^*$
$R\delta_0^* = 6000$
$R\delta_0^* = 4500$
$R\delta_0^* = 3000$
δ_ϵ^* (INCHES)
δ_ϵ^* X 10^3 (FEET)
$\left(\frac{u'}{u_e}\right)\frac{u_0}{\nu}$ X 10^{-3} (FEET^{-1})

FIG. 16.

Hence

$$\left(\frac{\delta_l^*}{\delta_u^*}\right)_{min} = \frac{1}{0.338}\,\frac{\epsilon}{R_{\delta_0}^*}\left(\frac{U}{\nu}\right) \qquad (1)$$

This ratio can be expressed in terms of momentum thickness by considering that the ratio of displacement thickness to momentum thickness is

$$\frac{\delta}{\vartheta} = 2.62 \text{ (for a Blasius profile)}$$

$$\frac{\delta}{\vartheta} = 1.96 \text{ (for an asymptotic profile)}$$

or

$$\left(\frac{\vartheta_l}{\vartheta_u}\right)_{min.} = \frac{2.62}{1.96}\left(\frac{\delta_l^*}{\delta_u^*}\right)_{min.} = 1.34\left(\frac{\delta_l^*}{\delta_u^*}\right)_{min.}$$

On a wind-tunnel model with suction strips the following values were derived from measured boundary-layer profiles upstream and downstream of a suction strip.

$$\frac{\delta_u^*}{\vartheta} = 2.35$$

$$\frac{\delta_l^*}{\vartheta_l} = 2.01$$

Using these values one obtains

$$\left(\frac{\vartheta_l}{\vartheta_u}\right)_{min.} = \frac{2.35}{2.01}\,\frac{\delta_l^*}{\delta_u^*} = 1.17\,\frac{\delta_l^*}{\delta_u^*}$$

A suggested mean value is

$$\left(\frac{\vartheta_l}{\vartheta_u}\right)_{min.} = 1.25\,\frac{\delta_l^*}{\delta_u^*} = \left(\frac{\vartheta'}{\vartheta}\right)_{min.} \text{ in previous notation} \qquad (2)$$

Substituting the value for δ_l^*/δ_u^* from Eq. (2) into Eq. (1) one finds

$$\left(\frac{\vartheta'}{\vartheta}\right)_{min.} = 3.7 \times \frac{\epsilon}{R_{\delta_0}^*}\,\frac{U}{\nu} \qquad (3)$$

or assuming $(R_{\delta_0}^*)_{crit.} = 4{,}500$ (equivalent to $(R_\vartheta)_{crit.} = 1{,}250$)

$$\left(\frac{\vartheta'}{\vartheta}\right)_{min.} = \epsilon \cdot \frac{U}{\nu} \cdot 823 \cdot 10^6 \qquad (4)$$

This simple relation, represented in Fig. 18, allows several important conclusions to be drawn for the design of suction surfaces.

Obviously, the ratio ϑ'/ϑ cannot become greater than unity. From $\vartheta'/\vartheta = 1$ follows the greatest value of U/ν which can be expected for a given surface finish defined by ϵ, or alternatively, maximum permissible roughness to attain a certain value of U/ν can be specified. The linearity for $\vartheta'/\vartheta = f(U/\nu, \epsilon)$ only holds for a certain range of ϑ'/ϑ. It can be expected that the straight lines will bend to the right as the case of distributed suction is approached, i.e., $\vartheta'/\vartheta = 1$. Higher values of U/ν may then be expected with a given surface finish, since the value of $(R_{\delta_0}^*)_{crit.}$ will become

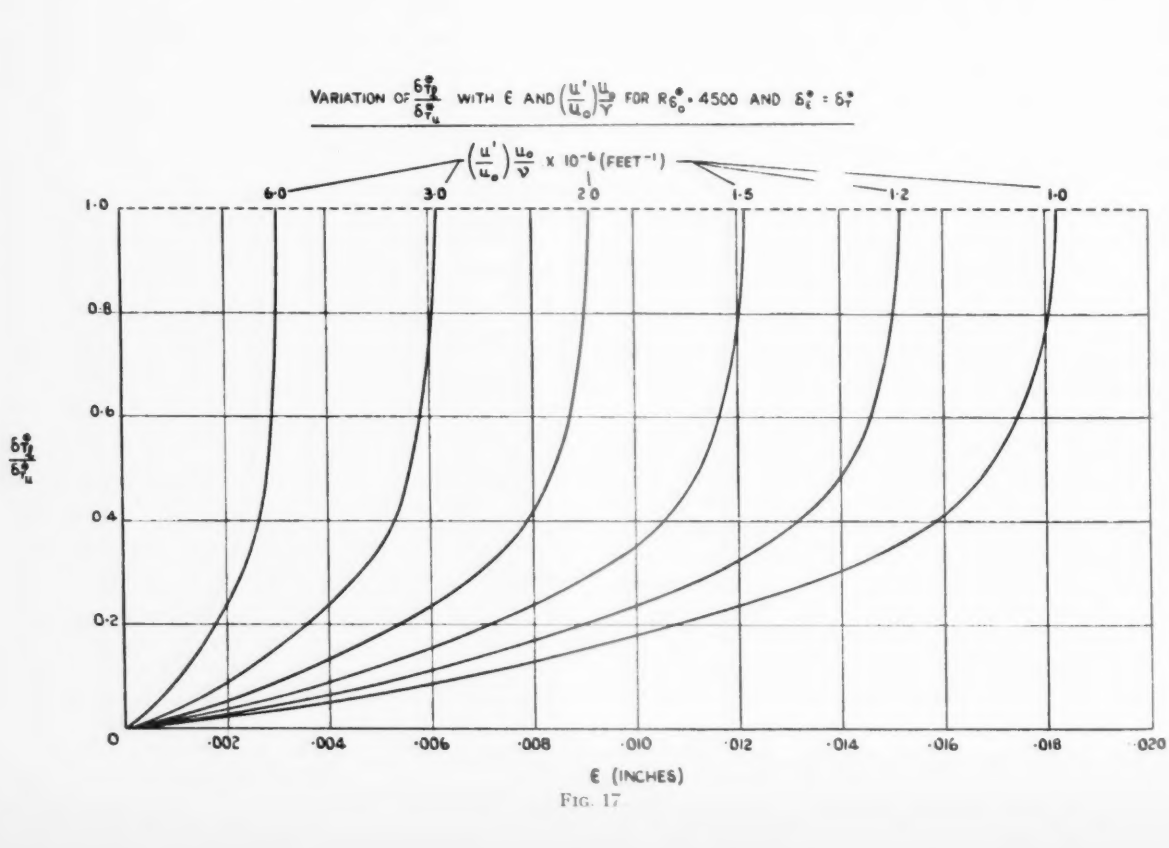


FIG. 17

greater than the conservative value derived from experiments with discrete suction sinks.

If a wing with discrete sinks was found satisfactory at a certain value of $(U/\nu)_1$, one can extrapolate how the ratio ϑ'/ϑ has to be increased by reducing local suction quantities (i.e., by decreasing the chordwise distance between sinks) in order to obtain a value of $(U/\nu)_2 > (U/\nu)_1$ with the same surface finish. (See Fig. 19.)

The Reynolds Number $\epsilon \cdot U/\nu$ emerges thus as the most important design criterion for suction surfaces.

General Conclusions on Surface Roughness

It is apparent from the above for either method of suction, discrete sinks or distributed suction, that requirements relating to surface finish become more stringent as the value of U/ν increases. This applies particularly to the forward part of the airfoil where the boundary-layer thickness is very thin. Here, a very smooth skin is essential, and it would seem advisable to rely on the natural laminar state of the boundary layer for a certain distance, since it is always easier to obtain a smooth impervious surface than a porous one.

The desired range of cruising lift coefficients determines the progress of the laminar front in chordwise direction, and it is worth observing that this progress decreases or reverses as the lift coefficients increase.

Although it is desirable to let the thickness of the boundary layer build up to a comfortable value before suction starts, it is necessary also to let the natural laminar front overlap the sucked portion of the surface by a reasonable margin, since the fringe of the natural laminar front is already in an "infectious" state tending toward instability. Airfoil contours should be carefully designed and velocity distributions checked to make sure there are no isolated kinks or adverse pressure gradients near the leading edge within the desired range of lift coefficients.

From a practical point of view, distributed suction is more difficult to achieve with a high standard of surface finish than with suction at intervals.

The ultimate choice would seem to be a compromise, i.e., suction through closely spaced spanwise sinks.

Roughness defined in the foregoing by the value ϵ of a roughness element includes inherent and acquired surface blemishes, that is, those due to manufacture and fly and dust accretion.

Means exist, either to protect the nose of the wing during take-off and climb to cruising altitude or to remove collected flies in flight.

Dust is collected generally only when the aircraft stands in the hangar. Special dust covers for the wings will become necessary in service to prevent dust collection.

Surface "waviness" is not synonymous with roughness. Excessive waviness has qualitatively the same destabilizing effect on the boundary layer as roughness, but, in general, it is found that a laminar boundary layer stabilized by suction will be found more inclined to overcome small adverse pressure gradients due to waviness than actual surface excrescences.

Double-skin panels in sandwich construction offer a good practical method for obtaining a firm and smooth surface with changes of curvature not exceeding 0.003 in. within a 3-in. curvature gage.

While it can be stated that boundary-layer suction is not a means to provide laminar flow over surfaces of relatively greater roughness than can be tolerated for ordinary laminar wing sections designed to provide a favorable pressure gradient, the existence of extensive zones of laminar flow, with reasonable care in maintenance, has been observed on a certain well-known type of British service aircraft.

PART IV

The Effect of Laminarization on the Performance of Aircraft

From the foregoing it would seem to follow that the highest cruising altitude would afford most favorable conditions for a laminarized aircraft in view of the reduction with increase of altitude of the all-important parameter U/ν for a given crusing speed.

While this is correct, generally speaking, insofar as difficulties connected with surface finish are concerned, considerations of optimum speed demand an equivalent reduction of induced drag when the frictional drag is lowered.

If reduction of induced drag is attempted by increasing the span of the wings, it will be found by weight analysis that the resulting increase of wing structure weight swallows up a good deal of the benefit that results from drag reduction due to laminarization.

When comparing performance of a "turbulent" aircraft, i.e., an aircraft where the wings have transition at the leading edge and where a turbulent boundary layer exists for the whole wetted surface of the fuselage and tail-unit, with a laminarized aircraft of equal span and weight, it is found that progressive degrees of laminarization necessitate a corresponding lowering of the cruising altitude for the laminarized aircraft and a simultaneous reduction of cruising thrust and powerplant weight to achieve the greatest improvement of range for a given pay load, or alternatively, the optimum pay load for a given range and fuel weight.

Fig. 20 shows the relative effect of various degrees of laminarization on range, cruising altitude, and thrust at optimum cruising r.p.m. All aircraft are of the same all-up weight (on take-off), carry the same pay load at the same cruising speed, and are assumed to have the same wing area and aspect ratio.

In the case of the laminarized aircraft suitable allowances have been made for extra weight, i.e., weight of suction plant, modifications to wing surface, ducting, etc.

The basic aircraft termed "turbulent" aircraft is a four-jet transport for which detailed weight and performance data were available.

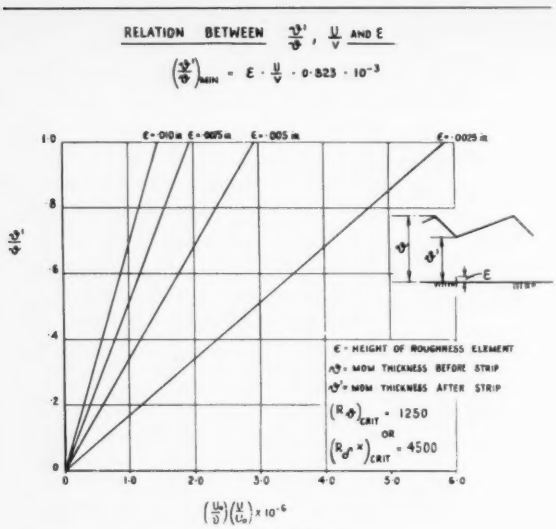

RELATION BETWEEN $\frac{\vartheta'}{\vartheta}$, $\frac{u}{v}$ AND ε
$\left(\frac{\vartheta'}{\vartheta}\right)_{min} = \varepsilon \cdot \frac{u}{v} \cdot 0{\cdot}823 \cdot 10^{-3}$
ε = 0·010 in
ε = 0·0075 in
ε = 0·005 in
ε = 0·0025 in
ε = HEIGHT OF ROUGHNESS ELEMENT
ϑ = MOM THICKNESS BEFORE STRIP
ϑ' = MOM THICKNESS AFTER STRIP
$(R_\vartheta)_{CRIT}$ = 1250
OR
$(R_{\vartheta^2})_{CRIT}$ = 4500
$\frac{\vartheta'}{\vartheta}$
$\left(\frac{u_0}{v}\right)\left(\frac{v}{u_0}\right) \times 10^{-6}$

FIG. 18.

The range of this aircraft at its cruising altitude (100) is marked 100, and it will be noticed that the basic cruising altitude is somewhat above that for which range would be a maximum. In other words, the basic aircraft flies somewhat below optimum cruising speed.

This basic aircraft is now subjected to progressive degrees of laminarization assuming either that the same power plant is maintained or that a progressive reduction of relative thrust and power plant weight takes place as frictional drag is reduced. Cruising speed is maintained constant.

It can be seen that progressive laminarization without corresponding reduction of power plant results in a relatively unimpressive increase of cruising altitude, as compared with that of the basic aircraft, and with practically no increase of range.

It should be noted, however, that an attempt to increase the cruising altitude of the "turbulent" aircraft by a corresponding amount could only be obtained with additional power plant and with substantial loss of range, assuming pay load remains the same.

Diagram 20 indicates how substantial increase of range for the laminarized aircraft results if cruising altitude is lowered and power plant weight progressively reduced with increasing degrees of laminarization.

For example, in the ideal case of an aircraft with completely laminar flow over the whole of its wetted surface, only one quarter of the thrust of the "turbulent" aircraft will be required, range being about 150 per cent greater and optimum cruising altitude about 20 per cent less.

For the more conservative example of say 50 per cent laminarization, the corresponding figures are: thrust reduction 50 per cent, range increase 45 per cent, and reduction of optimum cruising altitude 14 per cent.

These optimum figures are obtained with power plant weight reduced proportional to thrust reduction.

If the same power plant is carried by the laminarized aircraft as on the "turbulent" one, redundant engines being shut down for cruising flight, the remaining ones operating at optimum cruising r.p.m., the maximum range is substantially reduced, as the dotted lines and square dots in the diagram indicate.

Hence, in order to get the maximum economical benefit from laminarization it is essential that the power plant should be tailored to suit cruising conditions. Thus, either afterburning, rockets, or other means or radically new methods of take-off become necessary when reductions of cruising thrust of such magnitude occur that take-off thrust available with a reduced power plant becomes insufficient.

Otherwise, the potentialities of really low-drag aircraft of exceptional fuel economy are partially sacrificed to the accepted convention of unassisted take-off, a convention that is younger than the airplane itself. It is worth remembering, that launching, i.e., assisted take-off, made possible the flight of the first aircraft of the Wright brothers 50 years ago which was underpowered for direct take-off.

A different approach to that discussed above and illustrated in Fig. 20 would consist in designing *ab initio* an aircraft for the basic task of carrying a certain pay load at a certain cruising speed over a given range, stipulating at the same time a certain landing speed.

The "snowballing" effect of initial differences of component weights—in this case the reduced weight for power plant and fuel systems for the laminarized aircraft and its greatly reduced fuel weight—is a well-known design phenomenon. Hence, it is not surprising that the aircraft with laminarized wings, carrying the same pay load, at the same cruising speed, over the same range, will be substantially lighter and smaller than the equivalent "turbulent" aircraft.

If the range of the basic "turbulent" aircraft should already satisfy requirements—improvements due to lower specific fuel consumption can certainly be expected—the fuel saving due to drag reduction by laminarization can be converted, of course, into additional pay load.

Increase of low-density pay load (passengers) necessitates an increase of stowage volume and thus of wetted body surface. A certain amount of stowage volume is gained, of course, due to the reduction of fuel and power plant. However, the problem of laminarizing the surface of the fuselage gains importance for such aircraft designed to carry a large pay load of low density.

Reductions of power plant size or number of engines to supply the greatly reduced cruising thrust of laminarized aircraft (provided that deficiencies in take-off thrust are compensated by other means) enable the designer to choose unorthodox engine arrangements; for example, at the tail-end of the fuselage. Thus, the drag of the power plant would be reduced to a minimum with the added advantage of being able to arrange the passenger cabin ahead of the noise cone and outside the range of an exploding turbine wheel.

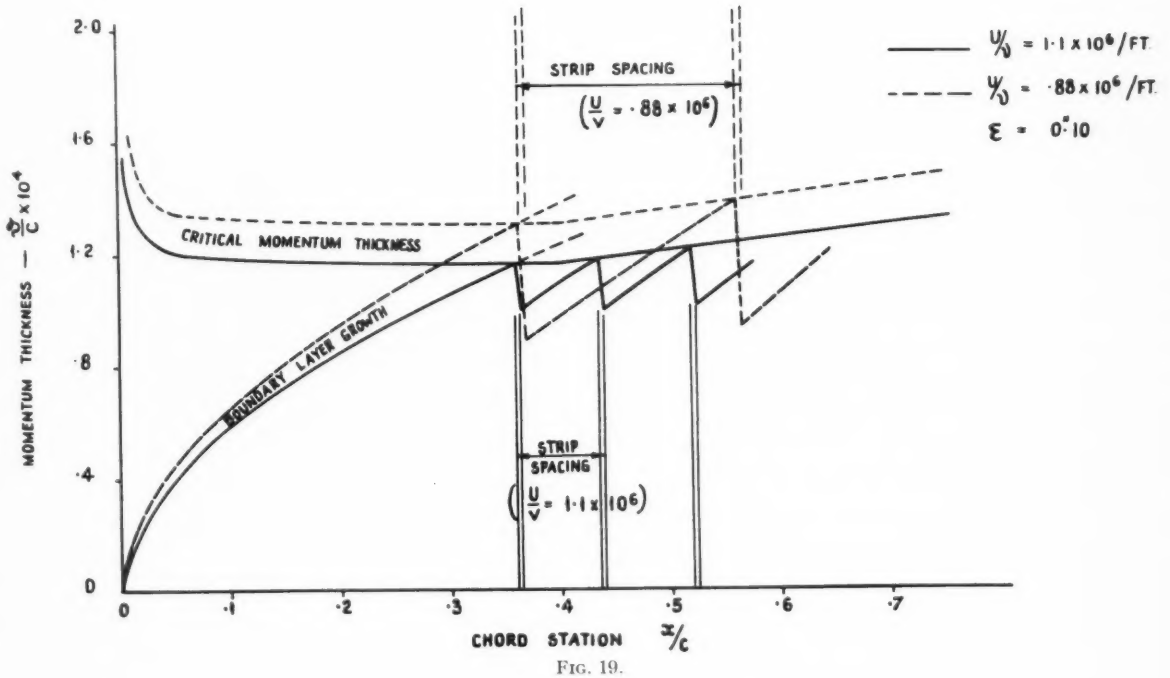

EFFECT OF [U/ν] ON STRIP SPACING
FOR THE SAME SURFACE ROUGHNESS
U/ν = 1·1 x 10⁶/FT.
U/ν = ·88 x 10⁶/FT.
ε = 0·10
STRIP SPACING
(U/ν = ·88 x 10⁶)
CRITICAL MOMENTUM THICKNESS
BOUNDARY LAYER GROWTH
STRIP SPACING
(U/ν = 1·1 x 10⁶)
MOMENTUM THICKNESS — θ/c x 10⁴
CHORD STATION x/c
2·0
1·6
1·2
·8
·4
0
·1
·2
·3
·4
·5
·6
·7

FIG. 19.

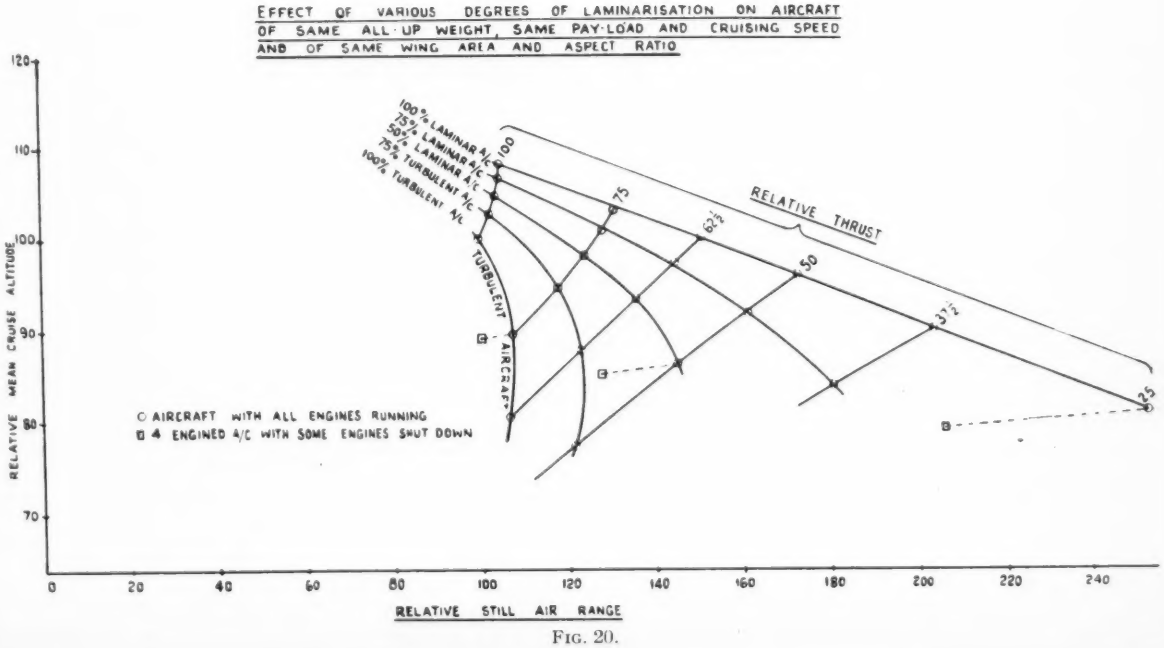

EFFECT OF VARIOUS DEGREES OF LAMINARISATION ON AIRCRAFT OF SAME ALL-UP WEIGHT, SAME PAY-LOAD AND CRUISING SPEED AND OF SAME WING AREA AND ASPECT RATIO
100% LAMINAR A/C
75% LAMINAR A/C
50% LAMINAR A/C
75% TURBULENT A/C
100% TURBULENT A/C
TURBULENT A/C
RELATIVE THRUST
100
75
62½
50
37½
25
○ AIRCRAFT WITH ALL ENGINES RUNNING
□ 4 ENGINED A/C WITH SOME ENGINES SHUT DOWN
RELATIVE MEAN CRUISE ALTITUDE
RELATIVE STILL AIR RANGE
120
110
100
90
80
70
0
20
40
60
80
100
120
140
160
180
200
220
240

FIG. 20.

Indirect reduction of form drag will thus result from the primary reduction of frictional drag. Fuel saving due to drag reduction has a surprisingly large effect on revenue from long range jet air liners. It has been estimated for the case of the Comet that a saving of only 5 per cent of fuel weight for the East to West transatlantic crossing, when converted into additional passengers, is equivalent to raising the annual revenue from a single aircraft by as much as $560,000 (£200,000).

The ideal source of thrust for a substantially laminarized aircraft is, of course, boundary-layer propulsion by accelerating the boundary layer somewhat in excess of flight velocity to obtain a thrust of sufficient magnitude to balance the induced and still remaining wake drag. Thus an improved propulsive efficiency approaching that of a propeller-turbine or equaling that of a ducted fan will result.

Compared with propulsion by straight jets, noise will be greatly reduced in view of reduced thrust coupled with reduced efflux velocity, a fact that may not only add to the comfort of air passengers but may also have significance in the field of military aviation.

Appendix

Let

c = chord
R_c = chord Reynolds Number
U = local flow velocity
U_0 = full stream velocity
$(\vartheta/c)_n$ = ratio of momentum thickness and chord for the boundary layer when reaching strip n
$(\vartheta'/c)_n$ = ratio of momentum thickness and chord after applying suction

Equally, $(\vartheta/c)_{n+1}$ and $(\vartheta'/c)_{n+1}$ are equivalent values for the boundary layer at strip $n+1$. Q equals suction quantity at a suction strip. The growth of ϑ/c along the chord can be expressed by

$$(\vartheta/c)_n = \sqrt{\frac{0.45}{R_c}}\,\frac{\sqrt{I_n}}{(U/U_0)^3} \tag{1a}$$

where

$$I_n = \int (U/U_0)^5 d(x/c) + I'_{n+1} \tag{2a}$$

the integration being taken from leading edge to first suction strip ($I_0' = 0$), first strip to second strip, etc., while I_n' is chosen to be consistent with R_c, U/U_0 and $(\vartheta'/c)_n$.

Let $(\vartheta/c)_n$ be the ratio of momentum thickness and chord for the boundary layer when reaching strip n.

After applying suction the ratio is reduced to $(\vartheta'/c)_n$.

The boundary layer grows again and reaches the value $(\vartheta/c)_{n+1}$ when it arrives at the consecutive strip $n+1$.

From the relations:

$$(\vartheta/c)_n = \frac{(R_\vartheta)_{crit.}}{R_c(U/U_0)_n} \tag{3a}$$

$$(\vartheta/c)_{n+1} = \frac{(R_\vartheta)_{crit.}}{R_c(U/U_0)_{n+1}} = \sqrt{\frac{0.45}{R_c}}\,\frac{\sqrt{I_n+1}}{(U/U_0)_n{}^3+1} \tag{4a}$$

follows by substitution:

$$I_{n+1} = (\vartheta/c)^2{}_{n+1}(U/U_0)^6{}_{n+1}\,\frac{R_c}{0.45} = I_n' + \int_{(x/c)_n}^{(x/c)_{n+1}} (U/U_0)^5\, d(x/c) \tag{5a}$$

Considering that

$$(\vartheta'/c)_n = \frac{\sqrt{0.45}}{\sqrt{R_c}}\,\frac{\sqrt{I_n^1}}{(U/U_0)^3{}_n} \tag{6a}$$

an expression can be derived for the ratio $(\vartheta'/c)_n \div (\vartheta/c)_n$ for any suction strip position:

$$\frac{(\vartheta'/c)_n}{(\vartheta/c)_n} = \frac{\sqrt{(U/U_0)^4{}_{n+1} - C_n\Delta_{n+1}I'}}{(U/U_0)_n{}^2} \tag{7a}$$

where

$${}_n\Delta_{n+1} = \int_{(x/c)_n}^{(x/c)_{n+1}} (U/U_0)^5\, d(x/c)$$

and

$$C = \frac{0.45R_c}{(R_\vartheta)^2{}_{crit.}}$$

It remains to establish the relations between the suction coefficient $C_Q = Q/U\cdot c$ and the ratio $(\vartheta/c)_n/(\vartheta'/c)_n$.

Referring to Fig. 7 it may be assumed that Profile II (after suction has been applied) is obtained by cutting off the lower part of Profile I (prior to suction) at a distance y from the surface, the removed part representing the sucked boundary layer.

If the strip width s is very small, changes of profile shape may be neglected in first approximation.

Since

$$Q = \int_0^y u\cdot dy = U\int_0^{y/\vartheta} \frac{u}{U} d\left(\frac{y}{\vartheta}\right) \tag{8a}$$

or

$$= C_Q = \frac{\vartheta}{c}\int_0^{y/\vartheta} \frac{u}{U} d\left(\frac{y}{\vartheta}\right) \tag{9a}$$

and at any strip n

$$\frac{C_{Qn}}{(\vartheta/c)_n} = \int_0^{y/\vartheta} \frac{u}{U} d\left(\frac{y}{\vartheta}\right) \tag{10a}$$

On the other hand, from a comparison between momentum thickness ϑ prior to suction and ϑ' after suction follows the ratio.

$$\frac{(\vartheta'/c)_n}{(\vartheta/c)_n} = 1 - \int_0^{y/\vartheta} \frac{u}{U}\left(1-\frac{u}{U}\right) d\left(\frac{y}{\vartheta}\right) \tag{11a}$$

Thus, Eq. (11a) and the previous expression (10a) give the relation between $C_{Qn}/(\vartheta/c)_n$ and $(\vartheta'/c)_n/(\vartheta/c)_n$ in parametric form.

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Management's Economic Interest in Safety

CARL M. CHRISTENSON*
United Air Lines, Inc.

Introduction

It is fortunate that the social concern for human life and the economic concern for the protection of both life and property are such that, when either one is provided for, the other is simultaneously and automatically, cared for. Regardless of the motives involved, therefore, whether they be humanitarian, economic, or blends and variations of each, consideration for the safety of operation is an essential element of good business, and its cost is more easily sustained than the price paid for the lack of it. Accepting this precept as fundamental, good business practice dictates a policy whereby safety must be given top management approval, sanction, and support.

The aviation industry is but 50 years of age, and in those 50 years we have progressed rapidly. As technical progress has been made by the engineer and scientist, the business mind has found ways and means of utilizing that progress in furthering the development of the air transport industry. And with each technical development, we have found new problems and experiences which have imposed great demands upon moral and economic considerations. It is evident, from the acceptance of the airplane as a means of travel by the traveling public, that the decisions that were made in the past have resulted in timely progress. On occasion, the costs of that progress in terms of time, lives, and money have been great but have proved through the years to be within tolerable economic limits.

Within the last 25 years the scheduled air transport industry has become a full-fledged component of worldwide enterprise. During this period the technical limitations of the airplane have disappeared before the ingenuity of men determined to overcome those limitations. Similarly, the limitations of operating know-how are gradually retreating before experience, science, and engineering.

With each of these limitations, the principal factor of concern has been the consideration of safety and economic liability. This concern has developed a profound interest on the part of management in the problems related to safety. This economic interest springs primarily from three basic factors: (1) the creation of confidence in the minds of the traveling public; (2) increasing efficiency in production and dependability in flight operations; and (3) the decrease in cost of operation.

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* Director of Safety.

Within the past 5 years the scheduled air transport industry has reached a comparable and competitive level of safety with surface carriers. It is important to realize that this is an acceptable level of safety as far as the general public is concerned but will continue to be acceptable only if consistent. Indeed, we have learned and are presently experiencing the fact that sporadic outbreaks of serious accidents in operations either in the air or on the ground become a serious and disturbing element within our business.

The aviation industry has just begun to tap the vast travel market that it has created with the introduction of speed, dependability, and flexibility into flight operations. The point-to-point costs of scheduled air transportation today is competitive with costs of equal surface transportation. Even so, many people still will not fly because flying to them is "strictly for the birds." Complete acceptance of air travel by the general public will come only through confidence. It will grow with each generation but will remain for many years a perishable attitude until all people become completely air minded.

Meanwhile, the entire aviation industry has a job to do because the attitude of the general public toward air travel is affected by the experiences of all segments of the industry. Headlines seldom are specific in their identity and thus create impressions which involve everyone associated with the news imparted by the headline. Thus, safety in aviation is a general problem for all to be concerned about and not specifically a job for one segment alone.

It is wise periodically to review our industry in the light of experience, obligation, and progress. This practice, in effect, guarantees the maintenance of the high standards of service which the scheduled air transport industry has developed within these past years.

In reviewing economic problems associated with safety in general, it is possible to identify economic facts that can be utilized to define the magnitude of the problem and, particularly, to indicate the amounts of money, time, and effort which can be budgeted to eliminate the waste of manpower and materials in our operations. Determination of such costs is largely dependent upon the accuracy and completeness of records pertaining to the problem. Thus the first step each company must take is the development of an adequate system of record keeping and incident reporting and the development of formulas for determining the true costs of the experience. It is similarly important that a trained staff be utilized in the compilation and analysis of those reports.

At this time it is possible to provide only preliminary estimates; however, these estimates compare favorably with data from other industry. It is not the intent here to define the economic problem of safety of any individual company, nor do the figures presented represent such experience. They are presented on the basis of average expectancy of an operating company in the light of existing statistical facts obtained from the National Safety Council, Civil Aeronautics Board, and Air Transport Association as well as individual company records.

The Air Transport Industrial Safety Problem

At the present level of air transport industry experience, we can expect in an organization of 15,000 employees a total of approximately 2,000 reported personal accidents, injuries, and first-aid cases each year, provided the reporting procedures are well organized and reflect the true experience in the field. Of these, approximately 20 per cent will be lost-time injuries and the remainder simple injuries and first-aid cases. The frequency rate within the air transport industry is approximately double that of the all-industry rate; however, the severity rate is equal to that of all industry. This indicates that perhaps the air transport industry experiences more personnel injuries and first-aid cases than the average industry but the severity is no greater. It is our experience that this severity factor can be reduced in scheduled air transportation to approximately one-seventh that of the average all-industry rate.

In dollars and cents, the cost related to this phase of the safety problem appears to be very close to the reported national average of $45 per employee. This provides management with a quick check on the magnitude of this particular problem. For instance, in an organization of 5,000 employees the cost will be approximately $225,000 per year; for 10,000 employees, nearly $450,000 per year; and for 20,000 employees, $900,000 per year. A recent check of this factor indicates that for an organization of approximately 15,000 employees, utilizing a hidden cost ratio of 4 to 1, the costs are almost $700,000 which, in effect, is within $25,000 of the national industry average.

It is important that each company determine a fair ratio between actual compensation costs, or direct costs, and invisible or indirect costs which are known to exist in relation to every such incident. The factor 4 appears to be fairly consistent with air-line operations, and within a short period of time a more accurate check on this item will be available.

Another incidental cost, which is a real one to business management, is the cost incurred by accidents in the home which result in lost time on the job and lost salary to the employee and which are not completely covered by compensation and insurance. It appears that this cost may average close to $100,000 a year for an organization of approximately 15,000 people. The problem is under study at this time.

The Equipment Damage Problem

In this area the problem of determining costs is a difficult one; however, ingenuity will provide a method of using standard operating statistics to determine the costs. Again, the real problem is that of complete and accurate reports concerning each incident. In this area, it is entirely possible grossly to underestimate the seriousness of the problem through failure to determine what happens to the air line when a ground accident occurs. The history typical of a minor accident, as referred to, is something like this:

An inbound aircraft taxiing in struck the tail cone of another aircraft with its wing tip. Immediately, both aircraft were out of service, delays occurred, passengers were inconvenienced, and no other equipment was available. Outbound trips and through trips were canceled. The passengers eventually used the competitor's aircraft or, after further delay, other trips of the company. And during this delay those passengers had to be lodged in hotels at company expense and provided with the embellishments necessary to quiet their justifiable irritation. Both aircraft were out of service for approximately 10 productive hours while spare equipment was utilized to fulfill schedule requirements, but, where this was impossible, substitutions and cancellations were made.

Usually the report on such an incident states that the damage required $50 worth of aluminum and rivets for one aircraft and $12 for the other; 12 man-hours for repair on the one and $3\frac{1}{2}$ hours for the other. The total cost was $81.80 for the first airplane and $11.25 for the second. However, on complete analysis, two trips were canceled, 60 passengers inconvenienced; all were accommodated on later departures and consolidations or on other air lines, this resulting in loss of revenue. Equipment substitutions were required to cover other schedules, affecting the line operation for the next 24 hours and involving three equipment substitutions and two cancellations from the other end because of equipment balancing. Thus, by the time we consider the true cost of such a small incident, instead of being justifiable operating expense it logically must be considered as unjustified business expense and therefore subject to elimination through good business judgment and operating practice. The difficulty in defining the magnitude of the overall safety problem, if accurate accounting is not made for each and every incident, is quite evident.

A method of determining these costs is being used at present as a sampling device, the basis for which is the use of existing information in the modern operating statistical section of the operations organization. The method requires that with each exposure the administration study the accident, report the facts, and determine the costs from the standpoint of its administrative interest. This divides the work and provides more complete information and a check list for the administration as an aid in developing true cost analysis. Fig. 1 is a brief diagrammatic chart of the method.

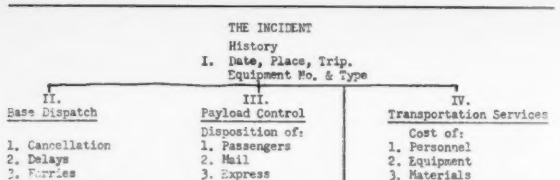


FIG. 1.

This may appear like a lot of detail for a minor ground incident, but the costs of such incidents, as determined by this method, are beginning to develop their true proportion in relation to operating costs. Of course, the real importance of such incidents to management is the economic concern for the destruction of dependability, which in some cases will infest the entire system following the incident. The insidious part about such incidents is that management receives little sympathy from the inconvenienced passenger, and these incidents tend to destroy acceptance of the service rendered by the operator.

The combined yearly costs of all ground equipment accidents, accidents involving ground equipment and aircraft, and ground accidents involving one or more aircraft—for an organization involving 300,000 operations a year—are estimated at between $600,000 and $900,000, depending on the efficiency of the total operation. Taxi accidents between aircraft by both flight crews and ground personnel have been notable contributors to the high overall cost. This safety problem is becoming more and more pronounced at highly congested airports where gate space is at a premium. The solution lies in straightforward production engineering of the ramp areas.

Miscellaneous Handling Damage to Aircraft

This is an insidious type of equipment damage that is costly to the air lines and a factor that comes under the heading of "tolerated" abuse. Such equipment damage includes the puncturing of holes in the tops of wings caused by dropping fuel nozzles, puncturing of the fuselages by fork lifts, pallets, carts, etc., damage to wing fillets by loading stands, and all the many other types of equipment damage incurred in service which places an added burden on engineering and maintenance. The puncturing of a fuel tank means pulling the equipment out of service for repair. All these things are expensive to the aviation industry. A one-year survey of this problem revealed the following:

Added Engineering Costs	$ 50,000
Added Rework Costs	40,000
Total Out-of-Service Cost	1,000,000
(100 per cent allocation)	$1,090,000

Flight Safety

This type of loss is by far the most serious of all the problems confronting the industry. Any effort to detail the exact cost of a major incident which would be characteristic of all such incidents would be impractical because of the great variation of the cost factors in each incident. However, it is possible to provide a partial estimate of average costs that are applicable to a major incident involving a four-engined transport and which are not to be construed as representative of any specific incident. Passenger liability is based on the $10,000-limitation that is representative of the legal limits of many states; furthermore, such settlements are seldom truly representative of factors associated with the incident itself.

(1) *Equipment Costs**		
Acquisition and improvement costs less depreciation		$ 610,000
Replacement costs		950,000
(2) *Fees and Expenses*		
Medical, transportation, local area, miscellaneous		60,000
(3) *Company Expenses—Payroll*		
Administrative, public relations, medical, personnel, legal, insurance, economic control, traffic and sales, passenger service, operations, engineering		70,000
(4) *Insurance Costs*		
Hull, Workmen's Compensation, air mail, cargo, other variables		250,000–975,000†
(5) *Revenue Loss*		
Equipment—replacement time, 2 years		
Revenue	3,000,000	
Less operating costs	2,300,000	
Net income		700,000
	Estimated Total	$3,365,000

It is clear that the cost of a catastrophic accident is a source of serious economic concern to the aviation industry. It is to be noted that these are only partial costs to the industry, because they do not account for the costs of the complete investigation—the costs of other industry representatives at the scene and their participation in technical phases of the investigation. Neither do they account for the untold costs of all the subsequent time-consuming repercussions following the incident.

Since this sample was taken, equipment costs, labor costs, as well as other charges, have risen approximately 25 per cent. Today this same representative incident would cost the industry close to $5,000,000. As we look into the future and the advent of jet transports in the $4,000,000 to $5,000,000 bracket, carrying up to 120 passengers, it is readily understandable that the industry must be realistic in its approach to this step forward. Recent events indicate the wisdom of application of the rule of the elimination of exposure as the true approach to the problems of safety in operation.

* Sample is for the 1948–1950 period.

† Insurance costs are so variable with each incident that attempts to arrive at an average have met with little success.

Aside from the catastrophic accident, the industry is confronted with the costs of the recurring major incident that involves no passenger injury. An organization such as we have been speaking of may experience about four major incidents each year. The total costs of such incidents will vary from $25,000 to $250,000, depending on the seriousness of the equipment damage. This type of incident may involve a landing in which the nose gear collapses, the costs running from $30,000 to $50,000, or perhaps a hard landing in which major wing damage is incurred and which costs in the neighborhood of $150,000. A fair estimate of the yearly costs for these incidents is between $200,000 and $500,000.

It may appear that these costs are exorbitant; however, they are not exceptional when compared to similar costs in other comparable industry. Other industries are faced with the same problems, and many of them, realizing the terrible price that can be paid for the lack of safety, are spending a great deal of time, effort, and money in combating the problem. We are actually talking about 10 per cent of the net income of the average operating air transport organization and the figure is all at the operating level. How much can we afford to spend to increase our net, say 5 per cent, which would be simply cutting the losses in half? It is a good question for the aviation industry to ask and for each company in consideration of its position to determine for itself.

Actually, the industry as a whole has been and is highly safety-conscious, as is indicated by the steady improvement in the overall safety of the operation. The great majority of the total effort of maintenance and service engineering is directed toward the three factors of *safety*, *efficiency*, and *economy*. The management of the scheduled air carriers have through the years been conscious of the importance of safety in operations. This is evidenced in the most highly developed and modern overhaul bases in the world. It is evident in the well staffed engineering organizations and the millions of dollars spent each year in meeting the day-in day-out requirements of operation. The highly skilled mechanics, electronics specialists, electricians, and others who provide continuous inspection, repair, and service to equipment are entitled to a large share of the credit for the steady progress in the safety of operations.

In the flight operations group, new and advanced training techniques are being placed into operation to provide better balance in this important field. With the advent of better facilities and equipment, flight operations will ultimately achieve the objective of making an accident purely accidental.

The industry has reached an acceptable level of safety. The problem now is to maintain a consistent level that will create complete confidence on the part of the general public. Ultimately, scheduled air transportation will prove to be the safest form of transportation in our civilization. The costs of reaching a higher level than that in our present experience are entirely justified for two reasons: first, the actual dollar costs of all types of accidents in the industry are too high; and, second, the confidence of the public created by a consistently high level of safety will more than pay for the costs of maintaining it.

The principal gain and benefit will be a more rapid and secure development of the industry in every phase. This will be true whether it be military, private, or commercial operation. The tremendous savings the industry can make in an all-out drive on the problems of aviation safety will benefit the nation as well as the industry. The most beneficial improvements can be made in the areas of engine reliability, traffic control, airports and approach facilities, and the overall understanding of the real problems of labor-management relations.

Safety means "freedom from danger." Its humanitarian application is the preservation of life and protection from injury. Its economic application is the preservation of capital investment and economic stability. It applies with equal force to the good will of an operating company in retaining the public's acceptance of our product and guaranteeing their willingness to fly with us. It is important to our individual and collective pride as related to our ability to do a good job and to maintain the highest standards possible within this highly competitive industry. Safety in itself, then, is a comprehensive aspect of the industry's problems. The basic consideration, from a purely economic standpoint, is the preservation of man power and materials. To that end alone its function is vitally important to sound business practice.

Application of Sailplane Performance Analysis to Airplanes*

AUGUST RASPET†
Mississippi State College

Introduction

The technique of using full-scale flight measurements as a means of investigating the quality of the flow around an aircraft has become a well established tool in sailplane development. In their striving for low-loss sailplanes the designers are eager to see how closely the final product approximates their performance computations. The final measurements are also a gage by which the craftsman's execution of the design can be judged. But above all a catalog of the advanced designs provides the designer with a foundation from which he can project the next design. In fact the process need not require a new design. The technique of measurement, diagnosis, and prescription of modifications can be applied to an advanced design in order to bring it to its ultimate performance. The world-distance record-holding sailplane RJ-5 was brought from a mediocre glide ratio of 29 as originally completed to a maximum glide ratio of 40 by a series of successive modifications.[1] See Fig. 1 for the progressive development of this craft.

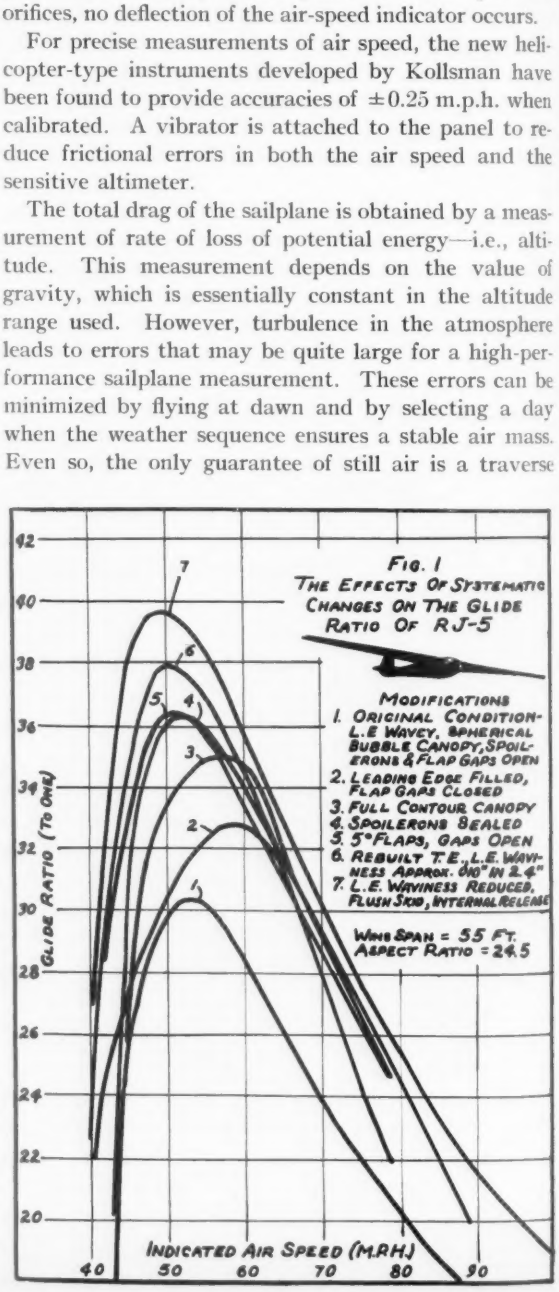
Since the sailplane performance analysis technique proved so fruitful on RJ-5, the writer began several years ago to investigate in a similar manner the performance of small personal planes. This paper is aimed at summarizing this work and projecting the results of these techniques for the improvement of current airplanes.

Sailplane Performance Measuring Techniques Applied to Aircraft

The determination of the total drag polar, $C_L = f(C_D)$, of a sailplane is a comparatively simple task. In order to determine the lift coefficient accurately, the air-speed measuring system of the sailplane is first calibrated with a trailing static bomb. In doing this the air-speed system of the sailplane, as well as the calibrating system, must have its pitot and static lines balanced against pressures resulting from the rate of descent of the sailplane. This is usually accomplished by adding a volume to the pitot side so that, when a pressure is applied simultaneously to the pitot and static pressure orifices, no deflection of the air-speed indicator occurs.

For precise measurements of air speed, the new helicopter-type instruments developed by Kollsman have been found to provide accuracies of ± 0.25 m.p.h. when calibrated. A vibrator is attached to the panel to reduce frictional errors in both the air speed and the sensitive altimeter.

The total drag of the sailplane is obtained by a measurement of rate of loss of potential energy—i.e., altitude. This measurement depends on the value of gravity, which is essentially constant in the altitude range used. However, turbulence in the atmosphere leads to errors that may be quite large for a high-performance sailplane measurement. These errors can be minimized by flying at dawn and by selecting a day when the weather sequence ensures a stable air mass. Even so, the only guarantee of still air is a traverse



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* The author gratefully acknowledges the assistance of George Lambros, who made the measurements on the Bellanca Cruisair and the Piper J-3, J. P. Mulloy for the Cessna 120 measurements, George Tabery for the Cessna 170B measurements, and Gordon Israel and Edward Swearingen for the Lodestar measurements. The author is indebted to The Cessna Aircraft Company for permission to publish the data on the Cessna 170B and to Lear Incorporated for permission to publish the Lodestar results.

† Head, Aerophysics, Department.

during which a plot of altitude against time yields a straight line. Any waviness in this line is indicative of rising and falling currents of air.

Fortunately, the application to airplanes of drag polar determination by sinking speed methods is not so critical to air mass motions as in the case of sailplanes, for airplanes have minimum sinking speeds that are four or more times greater than those of the best sailplanes.

The procedure for a drag polar determination on an airplane is either to remove the propeller and substitute a glider release (Fig. 2), by which the airplane is towed to an altitude of 10,000 ft. with a high-powered tow plane, or else to climb to altitude, stop the engine or engines, feather the propeller(s), and make the measurements while gliding down. On larger airplanes the latter technique is used so that the engines may be started again before landing.

FIG. 2. Bellanca with tow release attached, propeller removed.

Determination of Cooling Drag and Propulsive Efficiency

With the towing method, which is well suited to airplanes of 2,000 lbs. gross weight or less, it is possible to make glide measurements with the engine cowling sealed and opened, thus determining the cooling drag of the engine installation. Aerothermodynamic effects are of course neglected in this measurement.

Fig. 3 shows a typical measurement of power required versus air speed on a four-place personal airplane. The power-on curve was obtained from the engine speed and manifold pressure using the engine curves provided by the engine manufacturer.

From Fig. 3 we can readily determine the internal losses of the engine cooling flow by the difference of power required, cowl opened and cowl sealed. Such an analysis is shown in Fig. 4 where the air power required is obtained directly from Fig. 3 and the engine power required to obtain the cooling power is derived from the air-power curve and the propulsive efficiency of the airplane with cowl opened. The propulsive efficiency is easily obtained from Fig. 3 as

$$\eta_p = \frac{THP_r \text{ (cowl open)}}{BHP_r \text{ (power on)}}$$

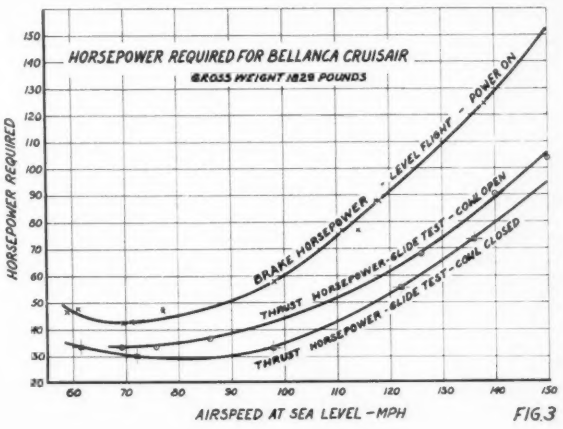

HORSEPOWER REQUIRED FOR BELLANCA CRUISAIR
GROSS WEIGHT 1829 POUNDS
HORSEPOWER REQUIRED
BRAKE HORSEPOWER - LEVEL FLIGHT - POWER ON
THRUST HORSEPOWER-GLIDE TEST - COWL OPEN
THRUST HORSEPOWER - GLIDE TEST - COWL CLOSED
AIRSPEED AT SEA LEVEL - MPH

FIG. 3

Overall Propulsive Efficiency

For the overall propulsive efficiency that would include the cooling losses one obtains

$$\eta_p = \frac{THP_r \text{ (cowl sealed)}}{BHP_r \text{ (power on)}}$$

A curve showing the variation of overall propulsive efficiency with speed of the airplane tested appears in Fig. 5.

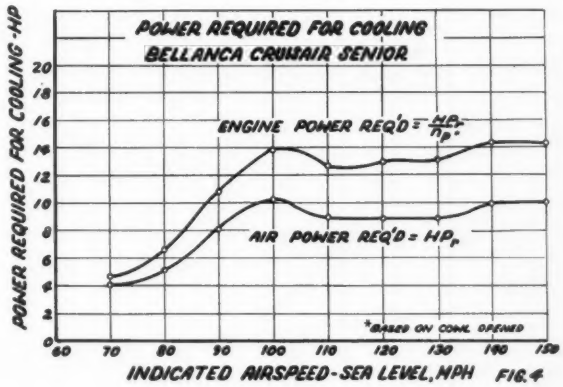

POWER REQUIRED FOR COOLING
BELLANCA CRUISAIR SENIOR
POWER REQUIRED FOR COOLING - HP
ENGINE POWER REQ'D = HP_r / η_p*
AIR POWER REQ'D = HP_r
*BASED ON COWL OPENED
INDICATED AIRSPEED - SEA LEVEL, MPH

FIG. 4

Minimum Drag and Efficiency Factor

When the data obtained from power-on and glide measurements for this airplane are reduced to the linearized drag polar, C_L^2 vs. C_D, one is able to separate

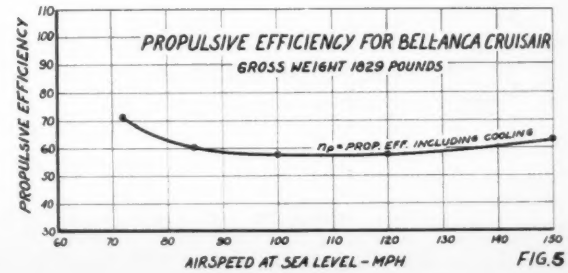

PROPULSIVE EFFICIENCY FOR BELLANCA CRUISAIR
GROSS WEIGHT 1829 POUNDS
PROPULSIVE EFFICIENCY
η_p = PROP. EFF. INCLUDING COOLING
AIRSPEED AT SEA LEVEL - MPH

FIG. 5

such performance parameters as minimum drag coefficient and Oswald efficiency factor, *e*. In Fig. 6 are shown the linearized drag polars for the four-place airplane being examined. The comparatively low efficiency factor of 46 per cent with power on would no doubt lead to rather large power requirements in climb and take-off.

In sailplane performance studies[2] it was found that a general cause of low efficiency factors was the interaction of the boundary layers over the fuselage and over the top surface of the wing. Separation, or at least a rapid growth of the boundary layer in the wing root, therefore results in rapidly rising drag. Fillets that tend to alleviate the adverse pressure gradient in the root should result in a better efficiency factor.

In the low lift coefficient regime of the polar, the drag deviates from its linear relation in such a way that the power required for high-speed flight actually rises faster than that predicted by the cubic speed relation. The cause of the deviation from the linear polar is a drag rise with reduction of angle of attack. This means that areas on the lower surface of the wing and fuselage are no doubt suffering a rapid boundary-layer growth with possible separation taking place. The location of such separated turbulent boundary layers can easily be determined by photographs of wool tufts on the airplane, the photos being taken over the speed range of the airplane.

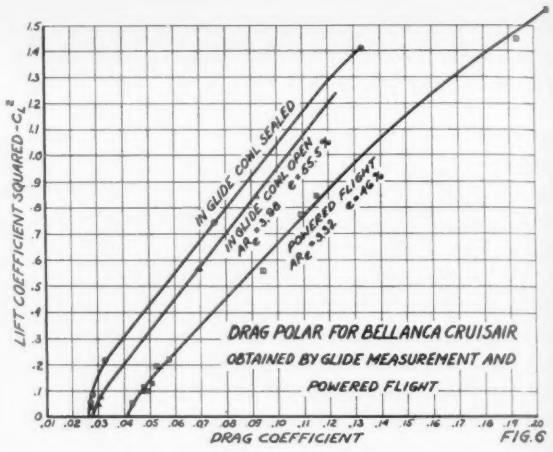


FIG. 6

In the foregoing discussion the application of glide measurements to airplane performance analysis was shown. From the results of glide tests and power-on measurements there are obtained: the drag polar, the overall propulsive efficiency, the cooling drag, indications of separation, and the Oswald efficiency factor. These are exactly the parameters a designer needs to know to determine whether his original assumptions and constants used in projecting the design were validly realized.

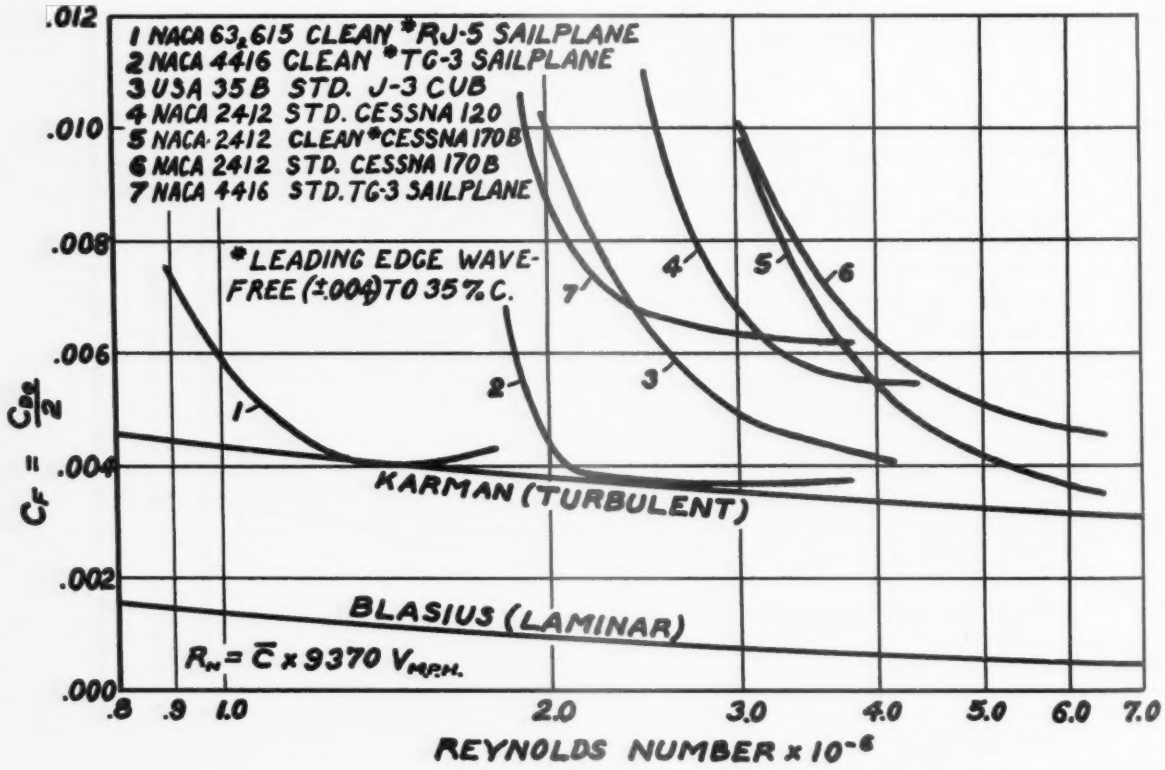

1 NACA 63₂615 CLEAN *RJ-5 SAILPLANE
2 NACA 4416 CLEAN *TG-3 SAILPLANE
3 USA 35B STD. J-3 CUB
4 NACA 2412 STD. CESSNA 120
5 NACA 2412 CLEAN *CESSNA 170B
6 NACA 2412 STD. CESSNA 170B
7 NACA 4416 STD. TG-3 SAILPLANE
*LEADING EDGE WAVE-FREE (±.004) TO 35% C.
KARMAN (TURBULENT)
BLASIUS (LAMINAR)
$R_N = \bar{C} \times 9370\ V_{M.P.H.}$
$C_{D_0}/2 = C_F$
REYNOLDS NUMBER x 10^{-6}
FIG. 7 PROFILE SKIN FRICTION COEFFICIENT VS. REYNOLDS NUMBER

FIG. 8. Navion sublimation photo, standard leading edge

AIRFOIL MEASUREMENTS

In the past, considerable effort was expended by both sailplane and airplane designers in the selection of an airfoil offering a high maximum lift coefficient, while at the same time having a low profile drag at low lift coefficients. Compromises of power coefficient for climb and thickness for structural lightness had to be made also.

However, after an airfoil was selected and constructed no further effort was made by the designer to verify his selection and the accuracy of construction of the airfoil by actual flight measurements. Yet the measurement of profile drag in flight is a relatively simple process using the integrating wake rake technique developed by Doetsch[3] for wind-tunnel measurements and adapted by Silverstein and Katzoff[4] for flight measurements. The construction and use of the integrating wake rake is so relatively straightforward that it should be a standard tool for every airplane manufacturer.

In Fig. 7 are displayed a number of profile skin friction curves taken in flight on standard production airplanes and sailplanes. Also shown are several curves for wings on which the leading edge has been smoothed to be wave-free to ± 0.004 in. measured on a curvature gage with points spaced 2 in. apart.

One can conclude from the profile skin-friction curves for the Cessna 170B in Fig. 7 that more important than the actual selection of the airfoil shape is the control of the smoothness on the leading edge of the airfoil as it appears on the production airplane. Needless to say, rivets, seams, and gaps on the leading edge will cause a transition from a laminar to a turbulent boundary layer.

METHODS OF DETERMINING TRANSITION

For investigating the nature of the flow over a wing, there is now available a simple process that consists of spraying a solution of naphthalene in petroleum ether onto the wing. The airplane is then flown at the desired lift coefficient. After a short time the white naphthalene film will sublime from regions where the flow is turbulent and remain on the regions where a low-shear laminar boundary layer exists. Toward the front of the leading edge where the shear in the laminar boundary layer is high, the film will sublime rapidly though not nearly as fast as in the turbulent flow. Fig. 8 shows a photograph of the nature of the flow on the leading edge of a Navion. Transition on the standard Navion occurs at the first seam or at the rivets ahead of the seam.

Another technique for determining the position of transition on an airfoil utilizes a standard medical stethoscope. The probe for detecting the transition is a small pitot to which is connected a long tube (Fig. 9). When the probe is placed on the surface in a laminar flow, a gentle hiss is heard, but, when it is in a turbulent boundary layer, a loud frying noise consisting of many high-order harmonics is heard.

Knowing the position of transition on both surfaces of the airfoil, it is relatively simple to obtain the profile drag using the Squire-Young formula.[5]

ANALYSIS OF FLIGHT MEASUREMENTS OF DRAG OF AIRPLANES

A convenient and valuable measure by which the quality of the flow over various airplanes may be compared is the plot of skin friction versus mean Reynolds Number, the latter being based on a mean length derived from area weighting:

$$\overline{RN} = \frac{(\bar{C}S_w)_{\text{wing}} + (\bar{C}S_t)_{\text{tail}} + (lS_f)_{\text{fuse.}}}{S_w + S_t + S_f} \times \frac{V}{\nu}$$

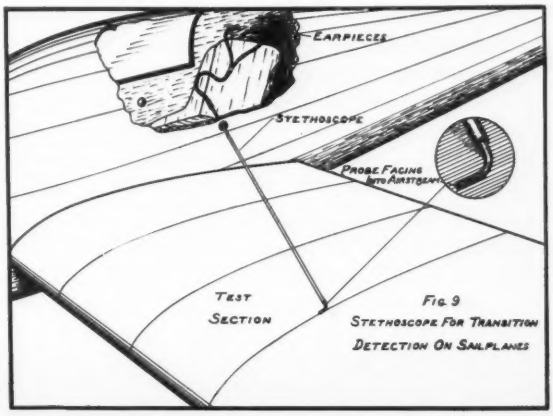
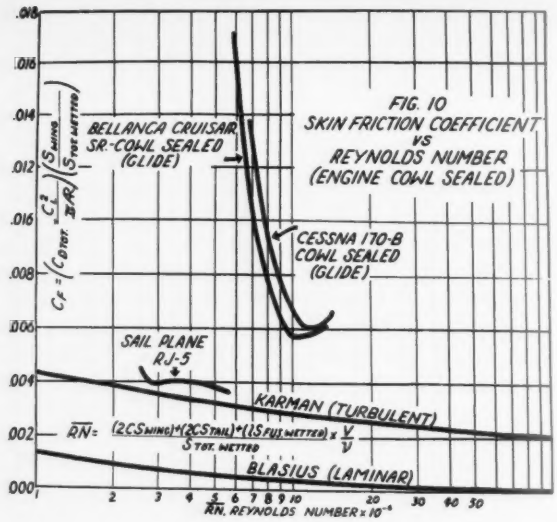
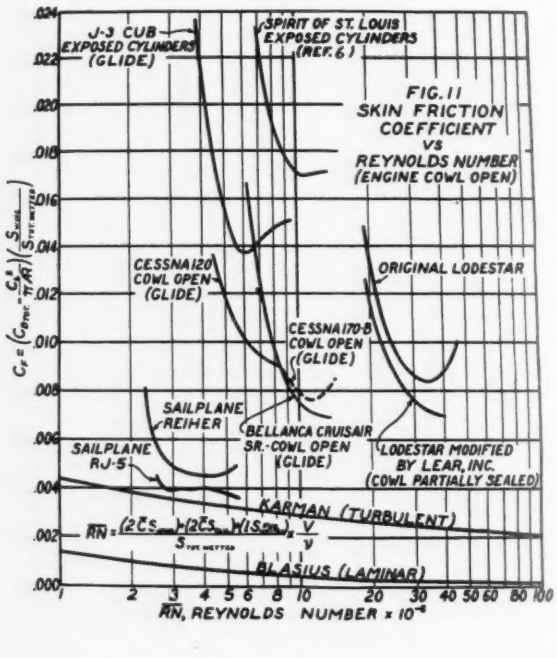


FIG. 9 STETHOSCOPE FOR TRANSITION DETECTION ON SAILPLANES





where S_w, S_t, and S_f are the wetted areas of the wing, tail, and fuselage, respectively, C is the average chord of the body in question, l the length of the fuselage, V the flight speed, and ν the kinematic viscosity. The skin-friction coefficient is obtained from

$$C_F = \left(C_D - \frac{C_L^2}{\pi \mathcal{R}}\right) \frac{S_w}{S_w + S_t + S_f}$$

The removal of the induced drag by assuming elliptic distribution of lift involves a small error, but, since the designer usually attempts to achieve elliptic distribution, such a scheme can prove useful until a direct way of measuring the induced drag is developed.

In Fig. 10 are shown the flight-derived skin-friction coefficient curves for three different aircraft. In these curves only the external aerodynamics are compared. It is evident that the minimum skin friction of the two airplanes is considerably above the full turbulent flat plate. This result can be ascribed to two causes: areas of separated flow and regions of accelerated flow where the skin friction is higher than on a flat plate. Even so, the fact that the skin friction of the sailplane RJ-5 approaches that of the turbulent plate flow clearly indicates that there is still a considerable gain possible in external airplane aerodynamics by reducing the skin friction of the entire airplane to that of a flat-plate turbulent flow.

The abrupt rise of the sailplane and airplane skin-friction curves at low Reynolds Numbers is indicative of excessive pressure drag resulting from separation, forward motion of transition, or excessive thickening of the turbulent boundary layer over the upper portions of the aircraft.

When the same procedure is followed as above, but with the cowl of the engine opened, there is also introduced into the skin friction the losses due to the flow through the engine nacelle. Fig. 11 shows the results of such a presentation for the sailplane, RJ-5, the sailplane, Reiher, the Piper J-3, the Cessna 120, the Cessna 170B, the Bellanca Cruisair, the standard Lodestar, and the Lear conversion Lodestar. In this work, no estimate of internal wetted area for the cooling airflow was made. However, the results are significant in showing the status of airplanes in the light of boundary-layer theory. These curves all show that there is considerable room for improving the aerodynamics of our airplanes merely by reducing pressure or form drag.

That such improvements can be worth while and economical can readily be seen from Fig. 12 where the thrust horsepower required for the Lodestar before and after modification are shown. At 250 m.p.h. I.A.S., the

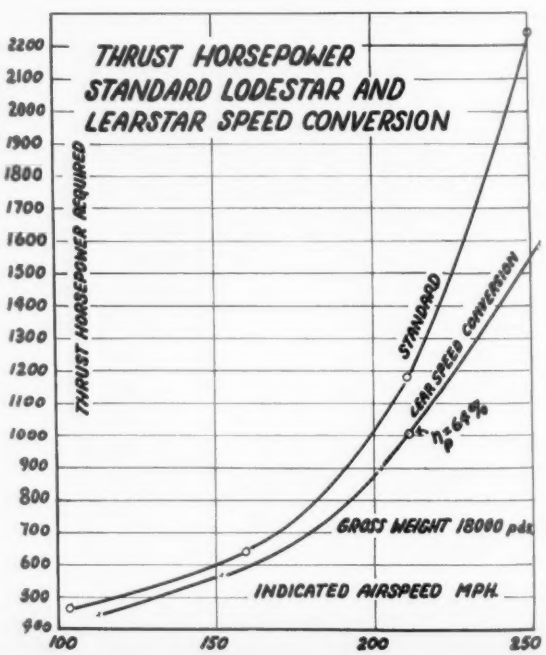


FIG. 12.

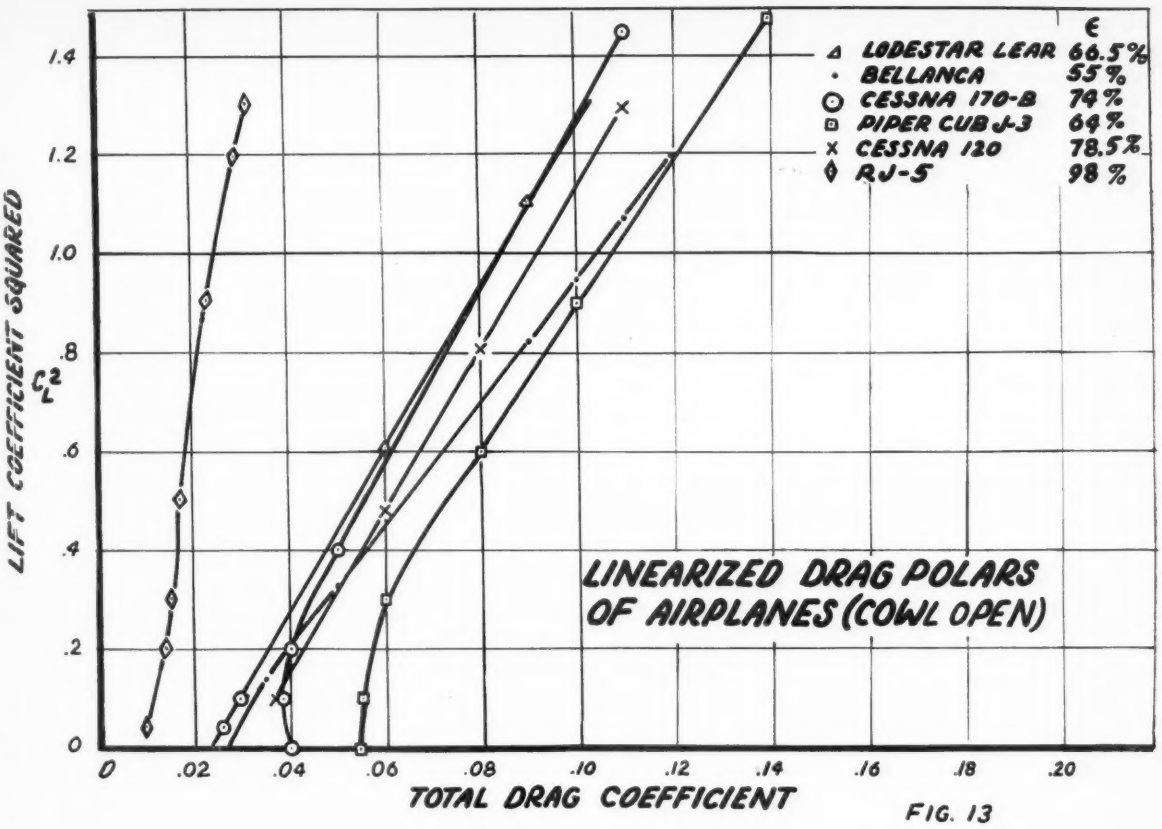


FIG. 13

Lear-modified Lodestar requires 700 thrust hp. less than the standard Lodestar which at the propulsive efficiency of 64 per cent (measured at 220 m.p.h. by engine calibration data) amounts to 1,100 b.hp. Referring to Fig. 11, one can see that this power saving was obtained from a relatively small fraction of the potential possible if the skin-friction coefficient were reduced to the turbulent flat-plate values being realized on what we call modern airplanes. The attainment of this goal would, of course, mean that extensive areas of laminar boundary layer would be needed to compensate for those regions of supervelocity over the airplane. Certainly it should be possible by a systematic process to remove all areas of separated flow on any of these airplanes.

Another means for comparing various airplanes is the linearized drag polars. In Fig. 13 are shown the drag polars of a number of airplanes measured in gliding flight with cowl open. It will be seen from the tabulated data on the figure that in general the low-wing airplanes possess comparatively low Oswald efficiency factors, which means that the control of the turbulent boundary-layer growth on the wing root on these airplanes is rather poorly accomplished. On the Piper J-3 and the Cessna 170B the parasite drag rise, as indicated by the deviation from the linear relation at low lift coefficients, detracts considerably from the cruising and high-speed performance of those airplanes. This is also true to a smaller extent for the Bellanca.

Conclusions

Full-scale flight measurements of a number of airplanes have been used to illustrate the potential of techniques used in sailplane performance evaluation. The interpretation of the results indicates clearly that certain trends in design would contribute to higher performance.

In particular the current emphasis on airfoil selection might profitably be realigned to an effort to maintain the leading edges of the production airplanes wave-free to tolerances permitting laminar flow at least to the minimum pressure points on both surfaces. Once this production problem is solved the promise of laminar airfoils can be realized.

More emphasis should be placed on the energy cost of cooling drag. On a current engine of 150 hp., the power required to cool the engine is 2.0 hp., yet when taken from the slipstream the cost of the cooling power is 14 hp. Weske's[7] studies show that, for a cooling blower efficiency equal to propeller efficiency and for a pressure drop through the engine cowl equal to the dynamic pressure, there is a net saving of 50 per cent in cooling power if the blower completely recovers the pressure drop through the engine cowl.

Another potential gain would involve bringing the overall propulsive efficiency nearer to that of the propeller alone. This implies improvements in flow of the slipstream over the cowl.

Insofar as external aerodynamics are concerned the results on the airplanes tested demonstrated that there is still considerable margin for improvement in eliminating zones of separated flows (pressure drag sources) and areas of rapidly growing turbulent boundary layers. As a means of approaching the skin friction of the turbulent plate flow the well-proved technique of using geometry to preserve the laminar boundary layer should be employed.

It is the author's sincere hope that the process of measurement, subsequent analysis, and rational modification of prototype will in the near future be used on production airplanes to achieve the gains that have been demonstrated by the work on the sailplane RJ-5.

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Guest Editorial

(*Continued from page 31*)

design. Pride must never be permitted to override common sense and the deep feeling of obligation to the air travelers. We are forced by competition and by the needs of the air lines always to better our performance—particularly speed—but we must never achieve these improvements by any sacrifice of safety.

In our military work the designer, engineer, and manufacturer are confronted with a somewhat different task. We are striving to create the most destructive instrument possible. And it looks as though we are quite successful now that we can team up with the A- and H-bombs. But we never lose sight of the fact that this same vehicle of destruction to the enemy must be the safest possible for our fighting pilots. They are the cream of the youth of our country. They are the foundations of the generations to come. We cannot afford to lose too many of them....

As one who became a part of the aircraft industry 40 years ago, I am extremely proud of still another important characteristic of the business and profession all of us love and respect.

It has been written that "as a man thinketh, so he is." Ours has been the task and duty of designing and building certain fundamentals into our products.

As aircraft people, we know there can be no compromise with integrity in design or with honesty of purpose and performance. As businessmen and servants of the government, we have developed the same approach, the same philosophy, and the same sense of responsibility.

I count it a great privilege to work with men whose guiding principle is the integrity and the profound, complete devotion by everyone to honesty in design, in accomplishments, and in financial matters.

Through the years we, as an industry, have been mainly supported by our government, and I consider it significant and heart-warming that I know of no leader in aviation who has not always throughout the years devotedly done his part to see that every dollar was spent to the fullest advantage possible at the time and under the circumstances.

Let us never forget this, or permit this dedication to principles, physical or financial, to change.

Development of
New Cargo Helicopters*

DONALD M. THOMPSON†

Office, Chief of Transportation, Department of the Army

Introduction

At the present time, major programs for the development of cargo helicopters are being pursued as rapidly as Government funds and engineering talents will permit. It is a safe assumption that these programs, which reflect the best engineering available in this country to date, will result in cargo helicopters that will fly and which will perform a cargo mission. After completion of the current developments, consideration will be directed toward the future designs. In order to be acceptable, these future designs must offer certain improvements over the helicopters now under development. This study is divided into two parts: The first section deals with the principal features of the helicopter and their relative importance in the selection of new cargo helicopters. The second section cites specific examples of some of the major difficulties in the helicopters available today and recommends a method of solution. The first step in the study is to determine the basic mission of the cargo helicopter.

Part I

Mission of the Cargo Helicopter

Considered in its broadest aspect, the cargo helicopter moves two types of cargo from one point to another. These two types are the soldier who walks by himself or is carried on board and equipment or supplies which must be loaded on board. In order to accomplish this mission, the cargo helicopter must be capable of carrying passengers and cargo internally. It is an aerial truck and as such needs to provide passenger comfort or cargo capacity similar to that of a large highway transport truck. We are not concerned with passenger compartment pressurization, heating, or general passenger comfort. We are concerned solely with a flying truck that can carry cargo internally. This is not intended to prevent external carrying of special pieces of cargo. It merely indicates that we are considering a cargo helicopter as a complete truck, not a tractor of a tractor-trailer rig.

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* The views expressed in this paper are those of the author and do not necessarily reflect the policies or doctrine of the Transportation Corps or Department of the Army.

† Chief, Engineering & Development Branch, Aviation Division.

Selection of New Designs

These aerial trucks have certain basic features in which the customer is interested. They are the primary design features that the customer will use in determining the desirability of new designs. They are (1) cruising speed, (2) ground time or loading time, (3) availability, and (4) pay load. This order of listing does not indicate the relative importance of the features. Each of these items will be defined in some detail before we proceed to evaluate its effect on the design of new helicopters.

The first listed item is cruising speed. This is the average speed at which the helicopter flies during a cargo mission. For the purpose of this analysis, times of acceleration and deceleration are neglected.

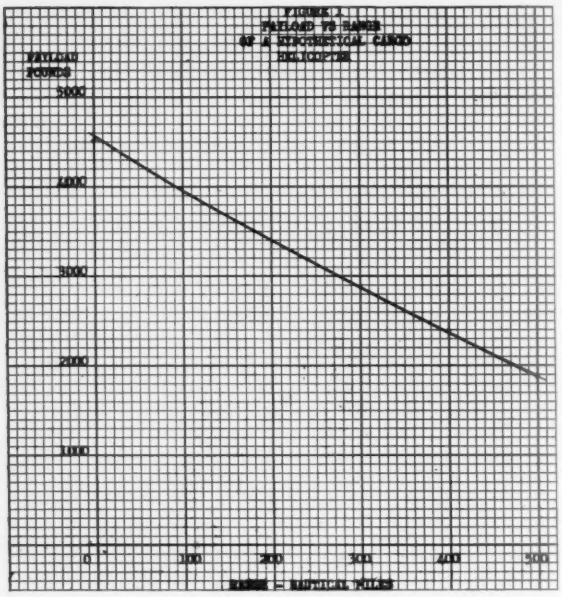
The second feature is ground time or loading time and refers to the period when the machine is not flying because of requirements of fuel or cargo. This ground time does not include maintenance or inspection time, which is included in availability.

Availability indicates the per cent of any given period of time during which the helicopter is available to perform a cargo mission. If the helicopter is on the ground being refueled or having cargo loaded, it is considered not available for the cargo mission. This broad definition of availability includes the effects of weather as well as maintenance. If the cargo helicopter is unable to rise off the ground because of adverse weather, it is not available for the cargo mission. It is, similarly, not available for the cargo mission if it is undergoing inspection, repair, or overhaul.

The last major design feature is pay load. This is the weight of the cargo which the helicopter carries during a particular mission. It does not include the weight of pilot, crew, fuel, or oil. These items are necessary for the operation of the helicopter and therefore are not considered as part of the pay load.

Effects of the Design Features

In order to determine the effect of the previously mentioned design features on the desirability of any cargo helicopter design, it is first necessary to determine a yardstick to be used for the measurements. The best yardstick is the number of tons of cargo which can be delivered during any given period. The most convenient period to use is 24 hours, or 1 day. The criterion used in comparison of cargo helicopters is the number of tons per day which can be delivered during



any mission. This obviously varies with the length of the mission and the type of helicopter.

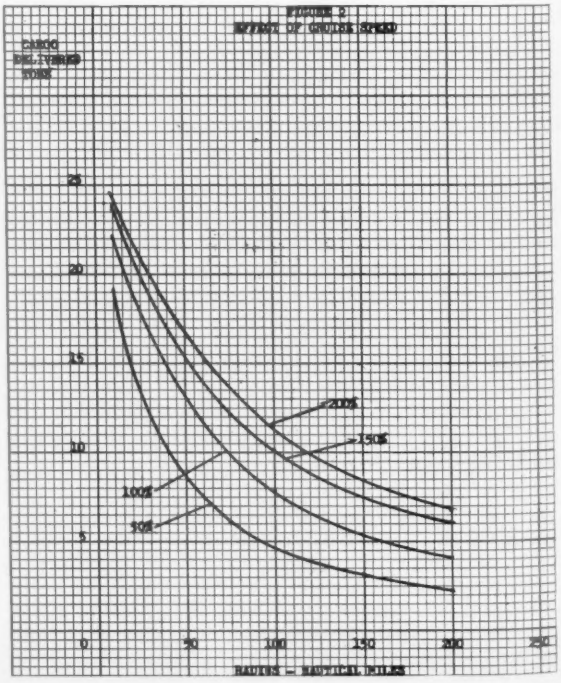
In order to secure the maximum benefit from any study such as this, the scope must be kept as broad as possible. A generalized helicopter is therefore selected to serve as a basis for the computation. The basic characteristics will be varied to determine their effect upon the number of tons of cargo carried per day. The load-carrying capacity of this arbitrary helicopter is shown in Fig. 1. This figure presents a plot of pay load versus range. The other design features are cruising speed, 100 knots; ground time, 1 hour per round trip; and availability, 50 per cent. The exact values assigned are of minor importance since each will be varied over a wide range.

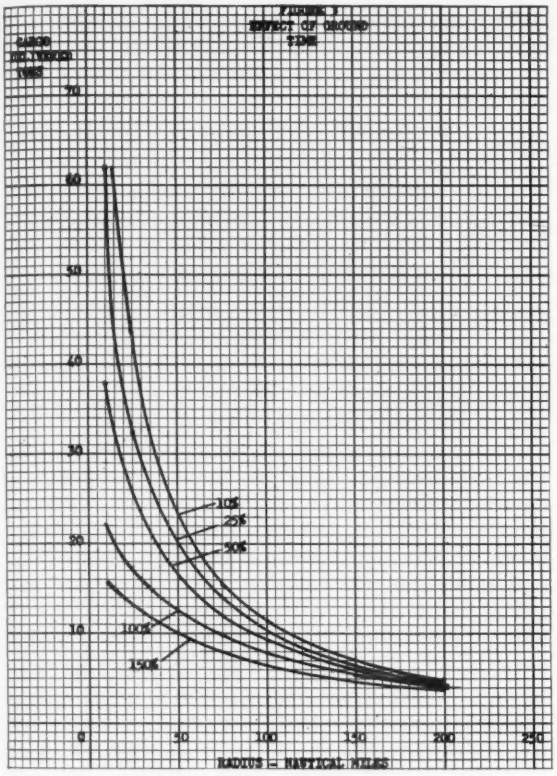
The other factor that must be established before proceeding with the analysis is a definition of the typical cargo mission. Herein it is assumed that the helicopter is fueled and loaded with cargo at point A. It then flies to point B at the average cruising speed. The radius is the distance from A to B. It is recognized that more cargo would be carried if the helicopter were fueled at both landing points. However, in most tactical situations, fuel will be available only at a rearward point and not in the extreme forward area to which the cargo is delivered. One of the basic advantages of the helicopter is its ability to deliver cargo rapidly to unprepared areas. The helicopter must not be limited to delivery of cargo to points that have refueling facilities. It is also recognized that some fuel could be saved if the load were carried in one direction only. However, more cargo will be carried if the helicopter is loaded for both flights. The results of this analysis would be the same even if the load were carried in only one direction.

The first of the variables to be considered is that of cruising speed. With the assigned values of 50 per cent availability, 1 hour ground time, and a cruising speed of 100 knots, the cargo delivered in tons per day is shown as a function of the radius in Fig. 2. This figure shows the effect of variations in cruising speed. The curve marked 100 per cent shows the cargo delivered when a cruise speed of 100 knots is used. If the cruising speed is decreased by 50 per cent, the cargo delivered is shown by the line marked 50 per cent. In a similar manner, the effect of increasing the cruising speed is shown by the curve for 150 per cent and 200 per cent. These calculations are all made with the other parameters of ground time, availability, and pay load remaining constant. This curve indicates that the increase in cargo delivered is not directly proportionate to an increase in cruising speed.

The next variable to be altered is ground time. The effects of this are shown in Fig. 3; in these calculations, the cruising speed is held constant at 100 knots and the availability at 50 per cent. The ground time is varied from the basic figure of 60 min. per round trip to 10 per cent of this value, or 6 min., and to 150 per cent of this value, or 90 min. It can readily be seen that, for the shorter missions, the effect of ground time on cargo delivered per day becomes tremendous.

The next parameter to be varied is availability. The cruising speed is held constant at 100 knots, the ground time at 60 min., and the availability varied from the base figure of 50 per cent, or 12 hours per day, to a minimum value of 6 hours per day, or 25 per cent availability, and a maximum value of 100 per cent availability. The results of these calculations are shown in Fig. 4. The percentage values expressed represent the variations from the basic value of 12 hours per day, which is marked 100 per cent. The curve marked 50 per cent represents an availability of 6 hours per day; the curve marked 150 per cent, 18 hours per day; and the curve marked 200 per cent, 24 hours



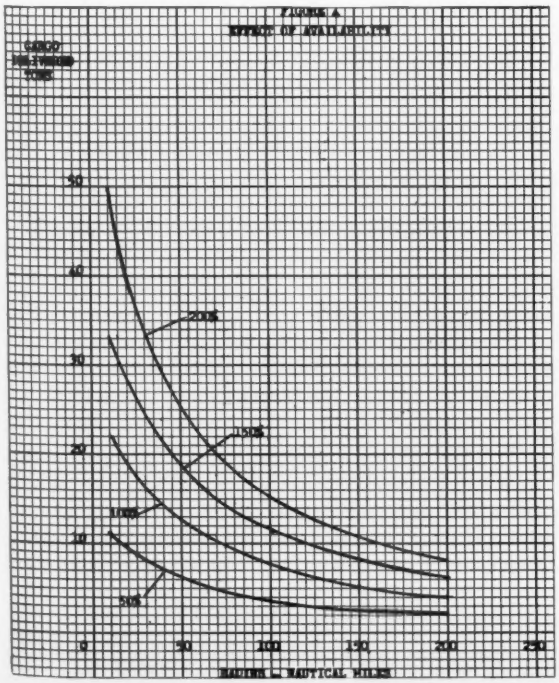


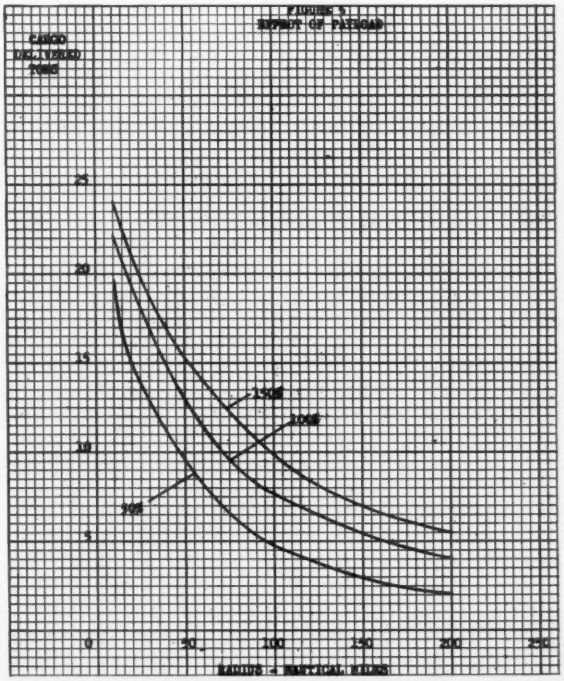
per day. The figure shows that the effect of availability is great regardless of the radius.

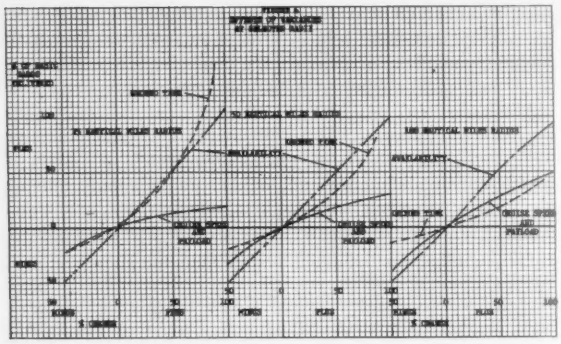
The last feature to be varied is pay load. In varying this, it is assumed that the rate of loading rather than the ground time remains constant. The cruising speed and availability remain constant. The results of these calculations are shown in Fig. 5. The line marked 100 per cent shows the cargo delivered as a function of radius for the basic helicopter chosen for these calculations. If the pay load carried on each trip is decreased to 50 per cent of the assumed value, the cargo delivered is shown by the curve marked 50 per cent. If the pay load is increased by 50 per cent, the cargo delivered is shown by the curve marked 150 per cent. It is readily seen that, for short missions, the effect of pay-load changes is relatively small. At the long radius mission, the effect of either increase or decrease in pay load becomes significant.

Relative Importance of the Design Features

Designers of the helicopters of the future will be faced with the necessity for compromise between the conflicting requirements for speed, pay load, availability, and short ground time. Fig. 6 has been prepared to give a nondimensional indication of the relative importance of the major parameters. Three arbitrary missions have been selected: 25 miles, 50 miles, and 100 miles. The percentage variation in cargo delivered is shown as a function of the percentage variation in the base parameter. The solid lines shows the variation in cargo delivered as the cruising speed is increased or decreased. Variation in pay load has the same effect and is shown by the same solid line. It is apparent that increases in cruising speed or pay load only provide relatively small increases in percentage cargo delivered on a 25-mile mission. This is also true at the 50-mile radius. At the 100-mile radius, the effect of cruising speed and pay load becomes more significant. The dashed line indicates the effect of ground time. At the radius of 25 miles or 50 miles, the ground time is a predominant factor. On a 100-mile radius, the effect of ground time drops below that of cruising speed and pay

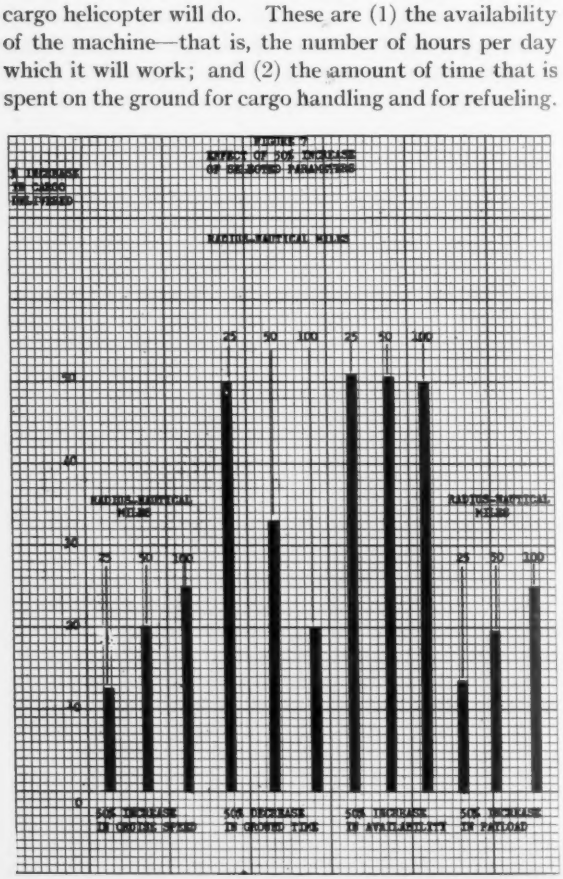






load. The remaining curve, which is represented by the dash-dot, shows the effect of availability. This is the predominant factor, regardless of the range. Only in the very short ranges is the effect of availability equal to or overshadowed by the effect of ground time.

The relative importance of the design features is also shown by Fig. 7. In this figure, the effect of an arbitrary improvement of 50 per cent in the parameters is shown. The three bars on the left indicate the effect of a 50 per cent increase in cruising speed. The next three bars show the effect of a 50 per cent decrease in ground time. The third set of three bars shows the effect of a 50 per cent increase in availability. The last three bars show the effect of a 50 per cent increase in pay load. This again shows that there are two predominant features that determine the amount of useful work the cargo helicopter will do. These are (1) the availability of the machine—that is, the number of hours per day which it will work; and (2) the amount of time that is spent on the ground for cargo handling and for refueling.



The effects of pay-load and cruising-speed improvements are secondary, except at longer ranges, and, even there, they do not overshadow the predominant effect of availability.

Conclusion

This study has shown that the key to improvement of the cargo helicopter lies in increasing the availability and in decreasing the ground time spent in loading and unloading cargo and in refueling the helicopter. Availability may be improved in two ways: through a decrease in maintenance time required and by increasing the ability of the machine to fly during adverse weather conditions. Of these two, the approach of decreasing the maintenance is by far the more fruitful. The basic ability of the helicopter to fly below bad weather indicates that few flights will be canceled because of adverse weather conditions. The effect of time lost to maintenance is direct and continuous, regardless of weather conditions. Reduction in maintenance time, therefore, appears to be the most important feature to be considered in future cargo designs.

The next feature, particularly for helicopters that are to operate over short ranges, is the ground time. The basic design of the fuselage of the machine appears as the predominant factor in ground time. Much time and effort have been spent in developing the cargo truck. This experience has shown that the square box-type structure with large doors provides for the more rapid loading and unloading of cargo. The future cargo helicopter must, similarly, provide for rapid loading and unloading of cargo. Balance requirements are also an important factor in ground time. Every minute spent in adjusting loads to provide proper center of gravity is a minute lost to the cargo mission. Rapidity of refueling is still another important factor in ground time.

The designers of future cargo helicopters must keep two factors foremost at all times:

(1) The helicopter performs no useful work when it is out of service for maintenance.

(2) The cargo helicopter is a flying truck and, as such, must be loaded and unloaded with the same rapidity as a truck.

These features are more important than increases in speed or pay load.

The particular importance of the feature of availability is the subject of the second portion of this study.

Part II

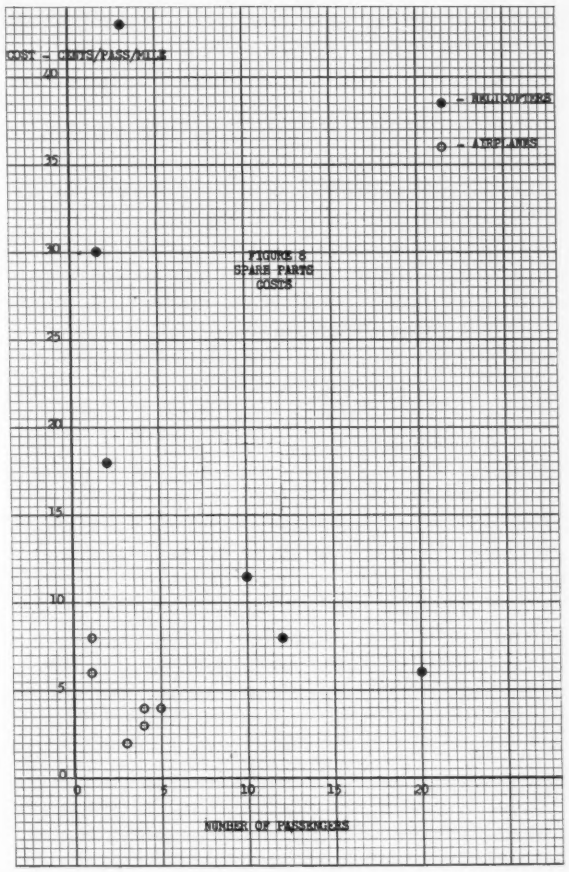
Background

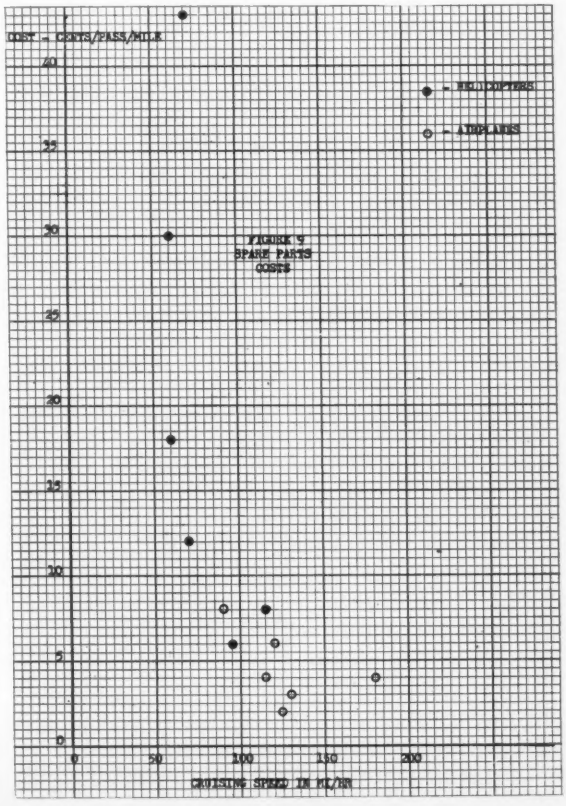
The Department of the Army is one of the largest customers for helicopters in the world. My remarks to you in this part of the discussion are those of a customer looking at the helicopter that he buys and uses today. The high cost of these machines is staggering. One can operate a DC-3 airplane, carrying 21 passengers, for the same price that one can put six people in a helicopter and shake along at a fraction of the speed.

At the moment, we are particularly concerned with the tremendous cost of maintenance of the aircraft and what this means when translated into both dollars and availability. The cost of spare parts alone for small helicopters is estimated at more than $80 per hour. This figures does not include labor, overhead, maintenance shops, depreciation, or any labor for overhaul of engines or other components. It is the dollar value of the parts necessary to keep the helicopter in the air. This cost may be expressed in other ways. Fig. 8 shows the cost of spare parts expressed in cents per passenger per mile as a function of the number of passengers carried. This presentation shows that when you board an Army helicopter you must pay more than $0.40 for each passenger for each mile traveled just to purchase the spare parts. From Fig. 8 two conclusions may be drawn: first, that both helicopters and airplanes are too expensive to maintain and, second, that helicopters are too expensive to maintain but, in the larger size machine, have relatively lower costs. Of these two possible conclusions, only the first is valid. The data presented show spare parts alone. On the same scale, the cost of spare parts for other transportation vehicles would be too small even to appear.

The same two conclusions can be drawn from Fig. 9, which shows the cost of spare parts in cents per passenger mile as a function of cruising speed. Here, again, the only valid conclusion from the standpoint of the customer is that both airplanes and helicopters are too expensive and that, of the two, the cost of spare parts for the helicopter is completely unreasonable. It must further be noted that the apparent reduction in cost of the larger higher speed helicopters is a wish but not yet a fact. The figures for those machines are educated guesses and not based upon experience, as are those for the small machines.

The importance to the customer of this high cost of maintenance is twofold. First, the availability is a direct function of maintenance time required. A good indication of the maintenance time required is the amount of spare parts that have to be purchased. If spare part consumption is high, maintenance time will be high and availability low. The second, and even more alarming aspect of high cost of parts, is the probability that the customer is purchasing helicopters that he cannot afford to operate. If the present high cost of maintenance continues there are only two alternatives. The first is to curtail production in order to buy spare parts with the limited funds available. The second is to continue to buy helicopters that soon will be nonflyable due to lack of spare parts. Either alternative will ultimately result in a great decrease in customer demand for helicopters. This matter of maintenance cost is of such vital concern to the customer that an analysis has been made to determine the causes of the poor service life of helicopters.





Analysis of Life of Helicopter Components

The major components currently causing the short life of helicopters are engines, transmissions, and rotor

blades. In attempting to analyze the causes of the short life of these components, we have found three general conditions that may individually or collectively be responsible.

(1) The conditions of climate and terrain in which the Army helicopter is forced to operate.

(2) The type of maintenance provided for the Army helicopter during operation and overhaul.

(3) Adequate or insufficient design of the helicopter.

Each of these three factors will be considered separately. The first is operating conditions. Regardless of any of the desires or the abilities of man, it is doubtful that he will change the face of this earth or the weather. Some power greater than man will be necessary if we are going to alter operating conditions. Therefore, in design of helicopters, the conditions that Mother Nature provides must be accepted without hope of alteration.

The second question is maintenance. It is often stated that poor maintenance occasions short life of helicopters. The facts are these: The helicopters are maintained by the best men that the United States, as a free democracy, can provide. These men are equipped, first, with the best training possible and, second, with the best tools that conditions permit. Major changes in the basic capabilities of the American individuals appear unlikely. Any maintenance improvements must come through improved design and not by a basic improvement in the human being.

The third possible cause is poor design. In order to examine the effect of design the three helicopter components are considered individually. The first of these components listed was the power plant. In this connection, two approaches may be taken: first, that all engines are unsuited and unreliable or, second, that the application of the reliability of engines to helicopters produces a short life combination. Experience shows that all engine life in Army service is too short. The life of engines in helicopters is much shorter than the life of the same engines when they are installed in airplanes. It has long been suggested that in helicopters the engine has a short life because it is worked to death. Fig. 10 shows the amounts of power required of the engine in a typical helicopter and in a typical airplane.

This chart compares the power requirements of a reconnaissance-type helicopter and an observation-type airplane during a typical flight at the same altitude and of the same duration. It can be seen that the helicopter engine is operating at a much higher power than that required of the engine in the airplane. The life of helicopter engines is shorter because the engine is run to death. Recommendations that the problem be solved by building lighter and more powerful engines are invalid. The engines that we have today represent, with few exceptions, the best that this country or the free world can produce. The solution to the problem lies in the proper selection and installation of presently available engines. The installation must be such that the engine will not be run to death.

The next component of the helicopter which is responsible for the high maintenance cost and poor availability is the transmissions. Essentially, the transmissions now used in helicopters are a collection of gears and bearings used to transmit power. Gearing and gear systems are not new. Statements have been made that the helicopter transmissions must be so light in weight, or operate at such high speeds, or receive such poor maintenance that they will of necessity be short lived. From the customer's standpoint these statements appear rather amazing. We have gears in trucks, trains, and even as reduction systems in aircraft engines. In order to check for any possible correlation between specific design requirements of the helicopter gear systems and their short life, studies have been made of the following gear systems:

(a) Reduction gears in four aircraft engines.

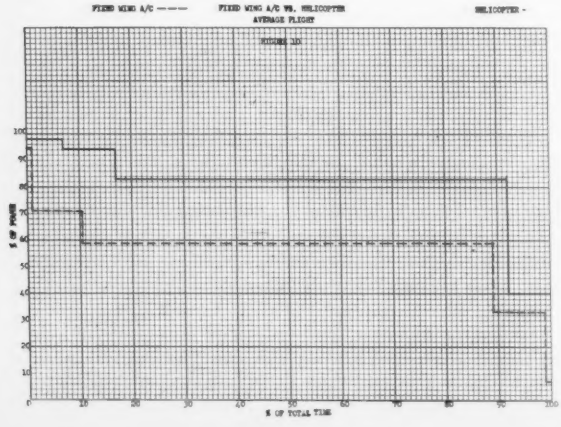
(b) Differential gears on four types of trucks.

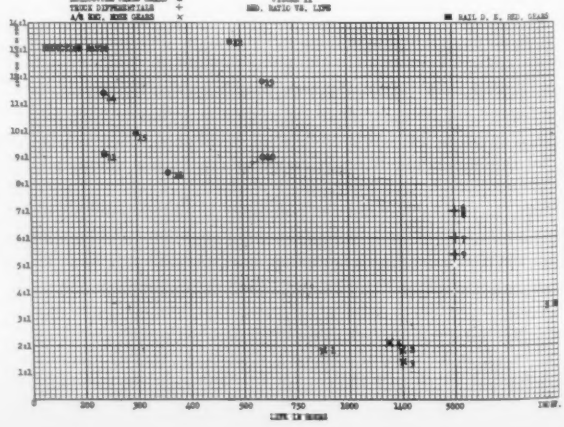
(c) Reduction gears on a represented type of diesel electric locomotive.

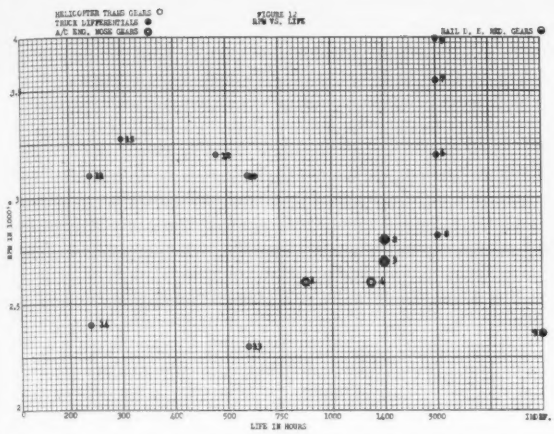
(d) Service helicopter transmissions gear systems.

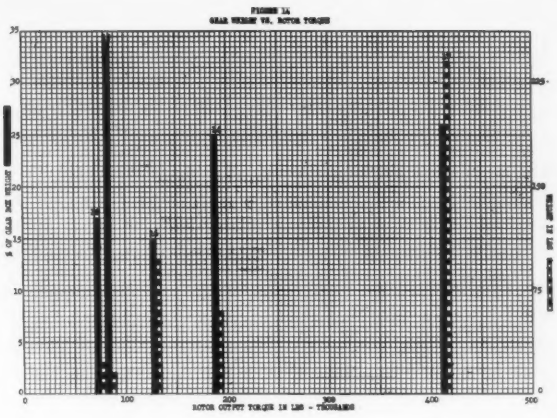
The life of these systems before overhaul varies from as little as 240 hours for some helicopter transmissions to an infinite life of the gearing in the diesel electric locomotive.

In order to determine the possible effect of design requirements, several sets of comparable data have been plotted. Fig. 11 shows the life of the transmissions be-





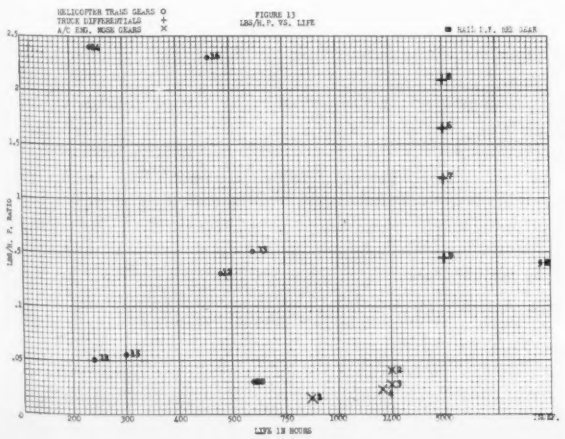


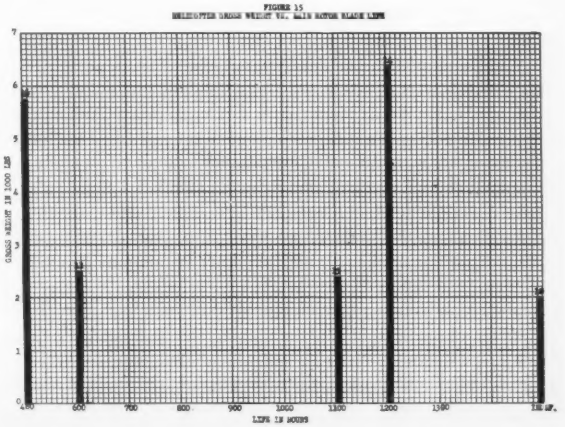


fore overhaul as a function of the reduction ratio. In order even to show the very short-lived helicopter transmissions, certain liberties have been taken with the horizontal scale. This is true not only for Fig. 11 but in all the presentations of life before overhaul. The scale has been altered to show a spread between various transmissions. Fig. 11 indicates that among the helicopters themselves there is no correlation between the reduction ratio and life. The life of the helicopter gear systems is very short compared to the life of other gear systems. In Fig. 12 the life before overhaul is shown as a function of the input speed. These data show that the high speed is not a cause of short life of helicopter transmissions. Truck differentials have a higher input speed and yet provide ten times the life of helicopter transmissions. Fig. 13 shows the effect of weight on life of transmissions. The helicopter transmissions are definitely not the lightest that we know. Even if the data were weighted to present the weight as a function of gear ratio, the short life of the helicopter transmissions would be outstanding.

The customer has suspected that there was little consistency in the design of helicopter transmissions. Fig. 14 shows the gear box weight as a function of rotor torque and also shows the gear weight as a percentage of the total transmission weight. These data show that there is no consistency between weight of transmission and the output of the transmission. They also show that there is no correlation between the output of the transmission and the weight of the gears as compared to the total weight of the transmission. These studies have led the customer to believe that there is no basis for explaining the short life of the helicopter transmissions except inadequate design. We are now building helicopters capable of carrying thousands of pounds. It appears ridiculous to continue with the unacceptable short life when, by the possible addition of a few pounds, we may achieve life comparable with that of other gear systems.

The last major component of the helicopter which has been considered in this study is the rotor blades. The helicopter rotor blade is an aerodynamic lifting surface. As such it should have life equivalent to that of other aerodynamic lifting surfaces. Unfortunately, while the life of airplane wings is measured in thousands of hours, the life of rotor blades is measured in hundreds of hours. The only comparison that has been drawn in this study is shown in Fig. 15, which shows the life of rotor blades as a function of the gross weight of the helicopter. There is no correlation between life of the blades and weight of the machine or any other parameters that can be selected. Here again the inconsistency is astonishing. From the standpoint of the customer, the life components must be increased.





Conclusion

Both parts of this study may be summarized by noting that, by mathematical analysis, it has been determined that availability is the most important feature of the cargo helicopter. The next most important feature is ground time. Availability is reflected directly in the spare parts consumption of the machine. The Army, as one of the largest customers for cargo helicopters, is being forced by the present designs to pay as much for operation of a six-passenger helicopter as is paid for the operation of a 21-passenger air liner. More specifically, the cost of spare parts alone, which does not include overhaul or installation labor, pilot cost, or fuel cost, is in excess of $80 an hour for a small helicopter.

This high cost is unacceptable. If positive design corrections are not made, two alternatives appear: One is to reduce new production and spend the limited funds available to build spare parts. The other is to continue to build helicopters that will soon be grounded for lack of spare parts. Neither of these two actions is desirable. It is up to you, the helicopter industry, to provide the engineering corrections necessary to make the helicopter suitable for use by the biggest customer.

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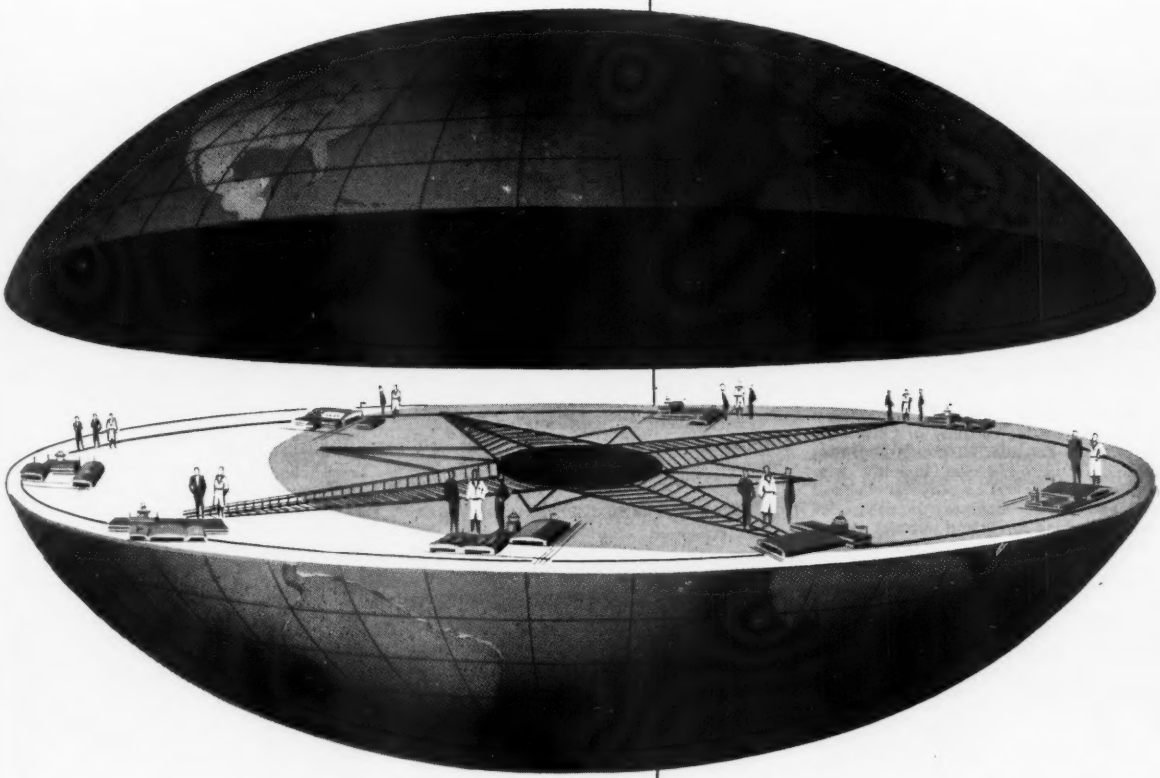

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IAS News

(*Continued from page 29*)

Tech on a scholarship during the 1932–1933 academic year.

From 1934 to 1936, Mr. Haynes worked as a Meteorologist and Hydraulic Engineer for the Los Angeles (Calif.) Flood Control District. In the latter year, he became an Instructor of Meteorology and Dispatching at the Boeing School of Aeronautics. He left there in 1939 to join the U.S. Weather Bureau, where he was placed in charge of the In-Service Training Section. In 1941 and 1942, he was an Air Safety Specialist in Meterology with the CAB's Safety Bureau. He returned to the U.S. Weather Bureau in 1942 as Chief of the Observations Section. Resigning from the Weather Bureau in 1953, he joined Lockheed Aircraft Corporation's Military Operations Research Division on last September 15 and was employed there at the time of his death.

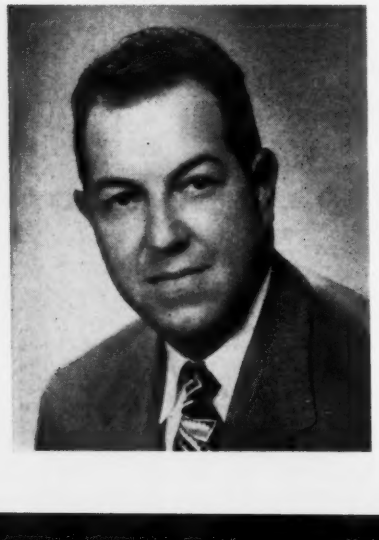
Mr. Haynes held CAA Private Pilot's Certificate No. 484315. He served for a number of years as a member of the NACA Subcommittee on De-Icing Problems and on the NACA Committee on Operating Problems.

Members on the Move

The purpose of this section is to provide information concerning the latest affiliations of IAS members. All members are, therefore, urged to notify the News Editor of changes as soon as they occur.

H. R. Arnold (AM), Manager of Foreign Relations and Administrative Assistant, Aviation Gas Turbine Division, Westinghouse Electric Corporation. Formerly, Assistant Manager, AGT Division, Westinghouse.

Edward I. Brown, MIAS, has joined Vickers, Inc., in the capacity of Chief Aircraft Products Engineer for the El Segundo, Calif., Division. He was formerly with Marquardt Aircraft Company as Section Head and Project Engineer in charge of accessory turbine drives and turbojet engine controls. Mr. Brown, a graduate of California Institute of Technology, served during World War II as an Engineering Officer.



Paul S. Baker (F), now Chief, Flight Test, Thermodynamics and Dynamics, Republic Aviation Corporation.

Harry S. Brenner (M), Director of Engineering, Olympic Screw & Rivet Corporation. Formerly, Standards Engineer, Airborne Equipment Division, Bureau of Aeronautics, Department of the Navy.

Harry W. Dorris, Jr. (M), President, Dallas International Aviation Company. Formerly, Design Development Engineer, Weapons Systems Evaluation Section, The Glenn L. Martin Company.

Theodore D. Gottlieb (TM), Development Engineer, Pressure Controls Group, AiResearch Manufacturing Company, Division of The Garrett Corporation. Formerly, Design Layout—Assistant Project Engineer, Pacific Airmotive Corporation.

John F. Haines (M), Vice-President and Chief Engineer, McCauley Industrial Corporation. Formerly, Chief Engineer, McCauley.

John R. Howard (M), now with Radioplane Company. Formerly, Supervisor of Field Service, Corporal Division, Firestone Tire & Rubber Company.

Aviation Cadet Vincent D. Kotecki, Jr., USAF (TM), now with 3302 Pilot Training Squadron, Spence Field, Moultrie, Ga.

Richard J. Kotowski (M), Development Liaison Engineer, Northrop Aircraft, Inc., Air Force Guided Missile Test Center, Patrick AFB, Fla. Formerly, Liaison Engineer—Product Designer, Aircraft Division, Kaiser Metal Products, Inc.

William C. Lawrence (M), Assistant Vice-President—Engineering, American Airlines, Inc. Formerly, Director, Development Engineering, American Airlines.

Edward F. Lazar (M), Assistant to the Vice-President and General Manager, Sperry Gyroscope Company, Division of The Sperry Corporation. Formerly, Director, Federal Department, Sperry Gyroscope.

Warner S. Lowe (TM), now with Flight Test Group, Ryan Aeronautical Company. Formerly, Flight Test Engineer, Convair Division of General Dynamics Corporation.

James S. Martin (M), Chief, Structure, Research, and Weights, Republic Aviation Corporation. Formerly, Chief Research Engineer, Republic.

Thomas A. McCarty (TM), Associate Engineer—Aerodynamics, Applied Physics Laboratory, The Johns Hopkins University. Formerly, Aerodynamics Engineer, Sverdrup & Parcel, Inc.

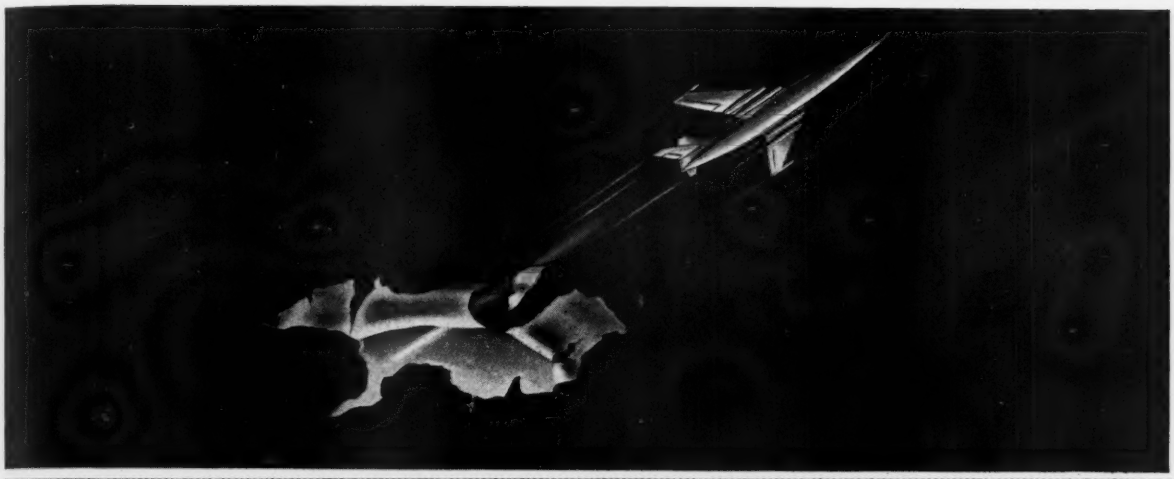
R. C. McGuire (M), Assistant to the Vice-President of Engineering, Eastern Air Lines, Inc. Formerly, Development Engineer—Structures and Systems, American Airlines, Inc.

Edward H. Heinemann, FIAS, Chief Engineer, El Segundo Division, Douglas Aircraft Company, Inc., was named by the Los Angeles Chamber of Commerce's Aviation Committee to receive the Aviation Man of the Year Award. The presentation was made at the All Airlines Ball held in Los Angeles on May 13. In presenting the award to Mr. Heinemann, Los Angeles' Deputy Mayor J. J. Irwin stated that "our Aviation Man of the Year's design contributions in the frontiers of advanced speeds and altitudes and in the design of successful operational planes for the country's defense forces have earned him this fine honor from his city."

Captain J. N. Murphy, USN (AF), Force Maintenance and Material Officer, Staff, Air Force Atlantic Fleet, NAS, Norfolk, Va. Formerly, Executive Director, R&D, BuAer, Department of the Navy.

C. E. Pappas (AF), Chief, Aerodynamics and Thermodynamics, Republic

Evert C. Hokanson, AFIAS, has joined the manufacturing firm of Wallace O. Leonard, Inc., where he is concerned with establishing sales engineering and contract administration activity. During his years in the aviation industry, he has served in aircraft design, flight test, air-line engineering, ground-equipment design and sales, instrumentation field engineering, and sales administration. Mr. Hokanson recently resigned from the position of Sales Administrator with G. M. Giannini & Co., Inc.



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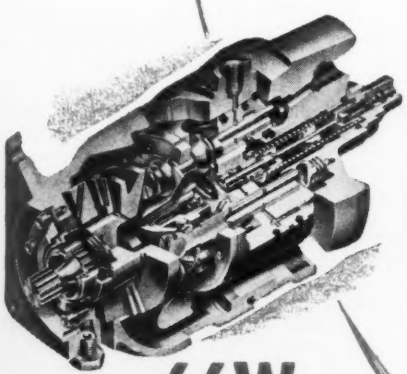

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Aviation Corporation. Formerly, Chief of Aerodynamics, Republic.

Jerry Pavelka (M), Chief of Aerodynamics, Republic Aviation Corporation. Formerly, Assistant Chief Aerodynamicist, Republic.

Benjamin T. Salmon (AF), Western Representative, The Norden Laboratories Corporation, San Diego, Calif. Formerly, Project Engineer, Convair Division of General Dynamics Corporation.

Charles A. Speas (M), Assistant to Engineering Manager, Flight Refueling, Inc., Baltimore, Md. Formerly, New Products Engineer, Sun Tube Corporation.

Edwin L. Thomas (M), Assistant Chief Engineer, Temco Aircraft Corporation. Formerly, Senior Structures Engineer, Aerophysics Laboratory, North American Aviation, Inc.

Norman L. Winter (M), Director, Federal Department, Sperry Gyroscope Company, Division of The Sperry Corporation. Formerly, Manager for U.S. Air Force Contracts, Sperry Gyroscope.

Whitley C. Collins was elected President and Chief Executive Officer of Northrop Aircraft, Inc., on May 17, filling the vacancy created 2 days earlier by the death of Major Gen. Oliver P. Echols, USAF (Ret.), FIAS (see Necrology, page 29). Mr. Collins has been a Director of Northrop since June of 1952 and has served as President of Radioplane Company, Northrop's wholly owned subsidiary, since its organization in 1938. Among the executive posts that Mr. Collins has held in the past have been Vice-President, General Manager, and a Director of Lockheed Aircraft Corporation (1929–1931) and Vice-President and a Director of Elastic Stop Nut Corporation of Americ (1940–1946). He is also currently Chairman of the Board of Holga Metal Products Company.

Corporate Member News

• **Aerojet-General Corporation, Subsidiary of The General Tire & Rubber Company. . .**The use of rocket assisted take-off units for the Boeing B-47B bomber has been announced by the Air Force. These high-thrust liquid-propellant RATO units, designed and produced by Aerojet-General, are believed to be the largest rocket power units ever designed for aircraft.

• **Air Associates, Inc. . . .**A 35-page catalog on aircraft electrical and radio equipment is available from the company's Department AD in Teterboro, N.J.

• **Airborne Accessories Corporation. . .**The 1954 ANGLgear catalog, recently issued by the corporation, illustrates and describes the ANGLgear standardized right-angle bevel gear units for aircraft and for industry. This 4-page catalog lists specifications for both sizes of ANGLgears: the $^1/_2$-hp. unit and 1-hp. unit.

• **Aircraft Radio Corporation. . .**A new ARC-16706 Course Indicator, designed for use with the company's Type 15D VOR Airborne Receiving Equipment, is now available. This indicator reportedly combines into one unit all functions of a cross-pointer meter and course selector. It fits into a standard $3^1/_4$-in. instrument hole and weighs 3.3 lbs.

• **Aluminum Company of America. . .** What is considered to be the world's largest press for the extrusion of metal has been installed at Alcoa's Lafayette (Ind.) Works and is now squeezing out giant aircraft parts. This press, which is capable of exerting a 14,000-ton pressure, permits extruded shapes to be made available in longer lengths (up to 110 ft.) and with more intricate cross section, greater cross-sectional area, and more weight in a single shape (up to 2,500 lbs.). This press will permit the production of 75S–T6 extrusions having a flattened width up to 34 in., with a skin thickness of only 0.156 in. This 14,000-ton press was loaned to Alcoa by the Air Force as part of its Heavy Press Program and has been the first major piece of equipment to begin operation under that program. When not squeezing out aircraft parts, the press will probably be kept busy in civilian production. . . . A tapered sheet and plate rolling mill, believed by the company to be the largest in the world, began production early in June at Alcoa's Davenport (Ia.) Works. This 144-in. mill is rolling tapered aluminum sheet and plate up to 10 ft. in width and 40 ft. in length for wing skins for U.S. military aircraft. Maximum thickness at the heavy end is 1.5 in. The rolling mill and some auxiliary equipment were supplied to Alcoa under a lease arrangement with the Air Force. Two new buildings enclosing the 52,000 sq.ft. necessary to house the operation were built by Alcoa. The Davenport Works has available the additional production equipment needed for use with this new Air Force mill. . . .Two of Alcoa's major operating divisions—the Die Castings Division and the Castings Division—have been consolidated. Alcoa's Castings Division now includes the die-casting works at Garwood, N.J., and Chicago, Ill., as well as aluminum and magnesium foundries and other operations at Cleveland; Detroit; Bridgeport, Conn.; Vernon, Calif.; and Buffalo.

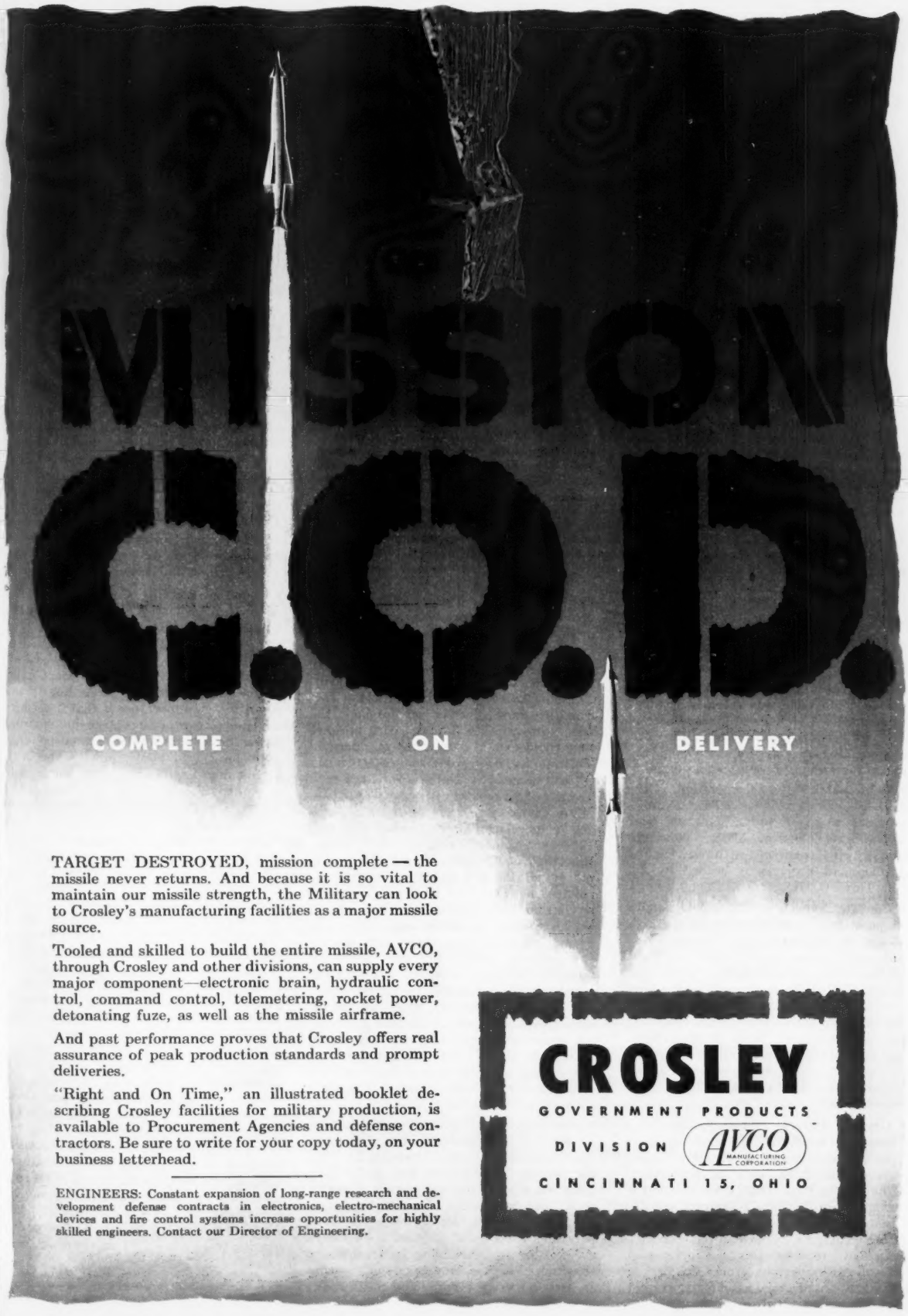
• **American Airlines, Inc. . . .** The election of new officers and the changes in assignments of other officers were announced on May 20 by the company's Board of Directors. These are: William Littlewood, FIAS, Vice-President—Equipment Development; M. G. Beard, AFIAS, Assistant Vice-President—Equipment Development; George C. Van Nostrand, Vice-President—Properties and Community Relations; William C. Lawrence, MIAS, Assistant Vice-President—Engineering; Arthur D. Lewis, Assistant Vice-President—Planning; and John J. Casey, Assistant Vice-President—Maintenance.

• **American Bosch Corporation. . .**Donald P. Hess, formerly President of American Bosch, has been elevated to the post of Chairman of the Board of the corporation. He succeeds Joseph E. Ridder who retired as Board Chairman of both American Bosch and its wholly owned subsidiary, Arma Corporation, but who remains as a Director of both concerns. Charles W. Perelle has been elected President and a Director of American Bosch and Arma. As President of Arma, he succeeds Kenneth H. Rockey who resigned last April 30 from that post. Mr. Rockey continues as a Director of American Bosch and Arma. Mr. Perelle, for the past 5 years, was President and General Manager of ACF-Brill Motors Company.

• **Bell Aircraft Corporation. . .**A technical fellowship enabling a young engineer to carry on graduate study during 1954–1955 at some university is being awarded by Bell to one of its employees. The aim of this fellowship is to permit a young engineer of recognized ability and potential to carry out advanced technical academic study, either in the field of previous specialization or in some other field, for the purposes of broadening and diversification. During the academic year, the employee's full salary will be paid, as well as tuition, books, and travel costs.

• **Bendix Aviation Corporation. . .**Bendix Radio Division has announced that it is developing an airborne radar system, Type RDR-1. The Bendix radar is being designed to a specification prepared by the ARINC Airlines Electronic Engineering Committee, except for the frequency. The Committee specified a frequency of 5,400 mc. (5.7 cm.); Bendix, for various practical reasons, is designing a 9,300-mc. (3 cm.) radar. The Division plans to have a prototype of a 3-cm. system sometime this summer, with production equipment by fall. A descriptive booklet on the Bendix RDR-1 Airborne Radar System is available and may be obtained by writing to Bendix Radio in Baltimore, Md.

• **Boeing Airplane Company. . .**A $5,800,000 flight-test facility, one of the largest and most modern in the United States, has been completed at the north end of Boeing Field, Seattle, Wash. This flight-test facility is contained in a hangar 785 ft. long by 200 ft. wide by 90 ft. high and in an attached one-story building. The hangar was built to accommodate future airplanes with wing spans up to 300 ft.; it can house five B-52 bombers. Quar



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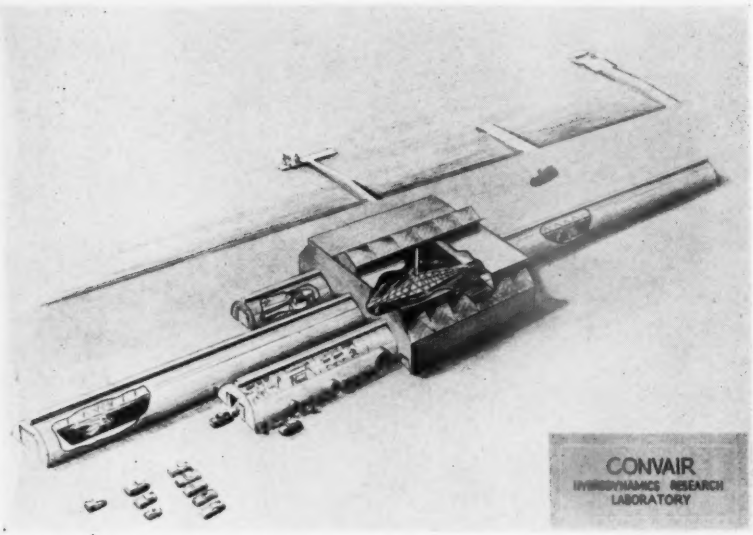

A Hydrodynamics Research Laboratory will be built by Convair Division of General Dynamics Corporation on its ramp at the San Diego Harbor. Designed primarily for testing seaplane models in towing basins, it will also permit expanded research on Navy seaplane projects. The laboratory will be 700 ft. long and will house four units—two 300-ft. towing basins, a 100-ft. sq. turning basin, and an office structure. Work on one of the 300-ft. towing tanks will get under way this fall; the other units are scheduled for construction within the next few years. The model seaplane towing basin, the first on the West Coast, will be 6 ft. deep and 12 ft. wide and will be lined with concrete. An overhead monorail, to which models being tested are attached, will be installed throughout the entire length of the towing basins. Wave-producing equipment will be installed in the large square tank.

tered in this new facility are the reorganized flight-test section of Boeing's Seattle Engineering Department, structural test facilities, experimental production shops, and Air Force flight operations offices.

• **Bristol Aero Engines Ltd. . . .**The corporate trade style was recently changed from Bristol Aeroplane Engines (Eastern) Ltd. to Bristol Aero Engines Ltd. The western division, Bristol Aeroplane Engines (Western) Ltd., retains that name.

• **Continental Motors Corporation. . .**The recently activated New Products Division occupies a 35,000-sq.ft. plant at 8647 Lyndon Ave., Detroit, Mich. This division, which is concerned with research and development projects, is headed by Lt. Gen. Doyle O. Hickey, USA (Ret.).

• **Convair Division of General Dynamics Corporation. . .**The Convair YC-131C, a Model 340 Convair-Liner converted to turboprop power, made its first test flight on May 20 at Carswell AFB. This is one of two YC-131C's being built at the Fort Worth Division under a USAF contract. The second plane will be flight-tested some time this summer. Both of these twin-engined military transports are for use as "flight test beds" for turboprop engines and are powered with Allison YT-56 turboprop engines.

• **Douglas Aircraft Company, Inc. . . .** Flight tests on the DC-7B were begun on May 20, with formal CAA certifications tests scheduled to begin in September. Although the basic DC-7 configuration is unchanged in the DC-7B, several new design developments have been incorporated. These include an increase in fuel capacity from 5,512 to 6,400 gals., an increase in take-off gross weight from 122,220 to 125,000 lbs., and a new flap linkage system that "provides optimum position of the flap for take-off." The DC-7B is powered with the Wright turbo-compound engine model DA4. . . .An agreement has been signed whereby Douglas leases the hangar, warehouse, and office space now occupied by Grand Central Aircraft Company at Tucson (Ariz.) Municipal Airport. The lease becomes effective on January 15, 1955, and runs for 3 years, with options that could extend it to an 18-year period. This facility, comprising some 600,000 sq. ft., will be used by Douglas for manufacturing and flight testing. . . .According to a recent company release, the Douglas budget for its scholarship program during the 1954–1955 academic year will reach an all-time high of $90,000. The bulk of this money will be used to aid employees and children of employees who wish to begin or continue their education on the college level. Awards for which employees may apply are adapted to three basic plans: (1) attending college full time while on approved leave of absence; (2) working part time (at least 50 per cent of the standard work-week hours) while attending school; and (3) working full time and taking approved courses after working hours (extension plan). The budget for the scholarship program also includes grants to a number of colleges and universities throughout the United States.

• **Elastic Stop Nut Corporation of America . . .**Four new lightweight lines of Elastic Stop nuts have been introduced by the corporation. These new lines cover "almost all aircraft locknut requirements—small and large sizes; hex, anchor, and gang-channel nuts; for all ranges of temperatures from −70° to 1,200°F." They are for use in assembling basic aircraft structures; in attaching components such as carburetors or pumps, and parts such as access panels; and in assembling and attaching accessories such as armament, electronic gear, and bombsights. Weight reductions are of the order of 0.5 to 2.5 lbs. per 100 nuts. These four new lines of Elastic Stop nuts are: the Blue J, the Type Y, the Type LH, and the ZA1W. The Blue J line of nuts is made of a high-strength aluminum alloy that meets the AN tensile strength requirements for steel nuts of the same thread size. These nuts average 65 per cent lighter than equivalent steel nuts and are interchangeable with standard AN 365 steel locknuts. The Blue J line includes nonfixed nuts (hex nuts), floating anchor nuts, anchor nuts, and gang-channel nuts, in sizes through $^1/_4$–28. The Type Y line of steel nonfixed nuts is intended to replace steel hex nuts primarily in the larger fractional sizes in which Blue J nuts are not made. The Type Y nuts average 25 per cent lighter than equivalent hex nuts because of the 12-point (double-hex) configuration and are available currently in sizes ranging from 10–32 through $^5/_8$–18. The Type LH line is of a new all-metal locknut design for applications of anchor and gang-channel nuts intended for use at elevated temperatures up to 550°F. Type LH nuts meet the same AN specifications as ESNA's equivalent beam-type nuts. The ZA1W line of beam-type all-metal anchor nuts is available in two types of stainless-steel bodies—one for service up to 800°F. and the other for service up to 1,200°F.

• **General Electric Company. . .**The Aircraft Accessory Turbine Department has announced that a small cartridge-type starter, known as the Model S-12, is now in full production. This is a new self-contained starter that is said to start a jet engine within seconds. According to the company, its importance is that it permits a plane to carry its own engine starting power for fast starts rather than depending upon local field power units. The S-12 starter uses a solid-propellant charge that is ignited electrically at the "push of a button." The rapid burning of this charge produces hot gases that turn a small turbine wheel engaged through a suitable clutch to start jet-engine power plants. This Model S-12 starter is used in the USAF's Martin-built B-57 bomber. It was also announced that the Aircraft Accessory Turbine Department has other types of starters in development, including one that uses a combination of jet fuel and compressed air. In this system, essentially the same cycle of events takes place. The pneumatic system is charged on the ground from air bottles and in flight from an engine-driven compressor. . . . A remote-controlled tail-turret system, capable of knocking down enemy interceptors in the night or fog, has been developed by G-E's Aeronautic and Ordnance Systems Division. This system, which is especially adapted for high-speed jet-airplane operation and which has been installed in the Boeing B-47E Stratojet bomber, consists essentially of a tail turret mounting two guns, a computer, control equipment, and search-track radar. The Air Force revealed that it has been delivering these armament units for nearly 3 years.

• **Walter Kidde & Company, Inc. . . .**The recently announced high-pressure air com-

Waldes Truarc rings replace old-fashioned fasteners . . . save assembly time...end scrap loss...increase operating efficiency

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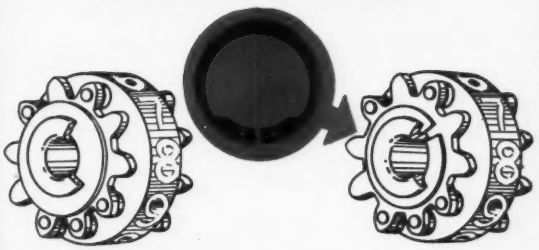
...precision-engineered business machine made even more efficient, and less costly to manufacture through the use of Waldes Truarc Retaining Rings.

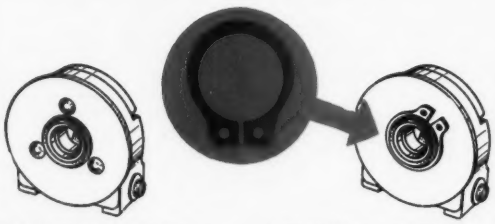
Multiplier Dial Assembly



Old Way. One-piece assembly was spun together. Spinning operation was costly, resulted in high scrap loss.

Truarc Way. Two-piece assembly is held together by one Truarc Ring (series 5108). Rejects: practically zero.

Electric Motor Governor



Old Way. Collector Disc assembly was formerly riveted, requiring skilled labor. Riveted Collector Disc could not be removed in the field.

Truarc Way. Truarc Ring (series 5100) replaces rivets, saves labor, material...improves Collector action. Collector Disc is easily replaced.

Intermediate Gear Shaft

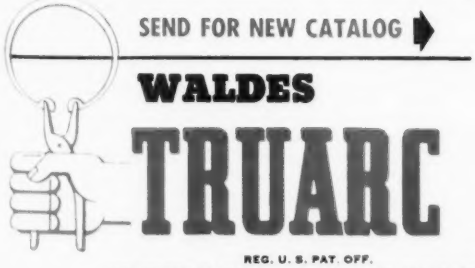
Old Way. Washer riveted on end of assembly for zoning control. Costly, troublesome, hard to obtain critical zoning required.

Truarc Way. Truarc E-Ring (series 5133) cuts assembly time, virtually eliminates rejects and final assembly and zoning problems.

Monroe Calculating Machine Company, Orange, N. J. uses various types and sizes of Waldes Truarc Retaining Rings. Use of Truarc has helped eliminate scrap losses, saved on material and labor, and resulted in increased operating and servicing efficiency of the product. Monroe plans to use Truarc Rings for every possible fastening operation on their entire line!

You, too, can save money with Truarc Rings. Wherever you use machined shoulders, bolts, snap rings, cotter pins, there's a Waldes Truarc Retaining Ring designed to do a better, more economical job. Waldes Truarc Rings are precision-engineered...quick and easy to assemble and disassemble.

Find out what Waldes Truarc Retaining Rings can do for you. Send your blueprints to Waldes Truarc Engineers for individual attention, without obligation.



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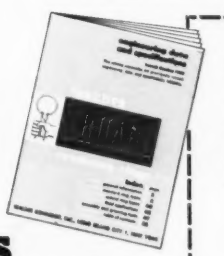
For precision internal grooving and undercutting...Waldes Truarc Grooving Tool!



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pressor, known as the "4D," was designed for use primarily on airplanes. The "4D" is a radial four-stage piston-type compressor that delivers 4 cu.ft. of free air per minute (at sea level) compressed to 3,000 lbs. per sq.in. It is so designed that it may be driven by an electric motor, a hydraulic motor, a direct connection from a reciprocating engine, or by an air turbine in conjunction with a jet engine. This unit weighs 11 lbs, and has an envelope of 10 in. . . .Daniel Mapes, Vice-President of the company, was awarded an honorary degree of Doctor of Engineering by Stevens Institute of Technology on June 12.

• **Kollsman Instrument Corporation. . .**A Sweep Generator, capable of covering its complete frequency range in a single sweep without tuning, has been developed by Kollsman. Designed primarily as a laboratory test unit, this instrument generates a sweep frequency signal with which bandpass and frequency response, standing wave ratio, and attenuation can be measured in conjunction with a detector and an oscilloscope. The Kollsman Sweep Generator comes in three frequency ranges, with each range covered in a single sweep. Type 2144–01 has a range of from 225 to 420 mc.; Type 2144–02, from 470 to 890 mc.; and Type 2144–03, from 850 to 1,275 mc.

• **Lear Incorporated. . .**Last June, the company occupied the newly completed administrative and manufacturing facility at 3171 S. Bundy Dr., Santa Monica, Calif. This new 50,000-sq.ft. plant is being used for the manufacture of electronic equipment and serves as the administrative offices of the company's LearCal and Research and Development divisions. The West Coast sales offices are also quartered in this building. Lear's other plants are located in Los Angeles, Grand Rapids, Mich., and Elyria, Ohio. . . .A new Director, Harvey H. Dwight, was added to Lear's Board of Directors. Among the various positions held by Mr. Dwight are those as President of Aircraft Engine and Parts Company, President and Director of Aero Credit Corporation, and President, Treasurer, and Director of American Aircraft Associates, Inc. The first Learstar off the company's production line at Santa Monica, Calif., made its first flight on May 10. This ship, which is designed for a normal cruising speed of approximately 300 m.p.h., is said by Lear to be the fastest airplane ever put into volume production specifically for the private transportation of business executives and the fastest of all production twin-engined transports powered by reciprocating engines. The Learstar may be powered with any Wright 1820-series engines up to and including the 1,525-hp. C9HE. While the Learstar is officially classified as a new-type airplane, it utilizes as its basic structure major components of the Lockheed Model 18 Lodestar air frame. Lear states that virtually all of these components have been modified to greater or lesser degree to provide reduced aerodynamic drag and, in many cases, increased structural strength, greater ease of maintenance, decreased vibration and noise factors, and added safety features.

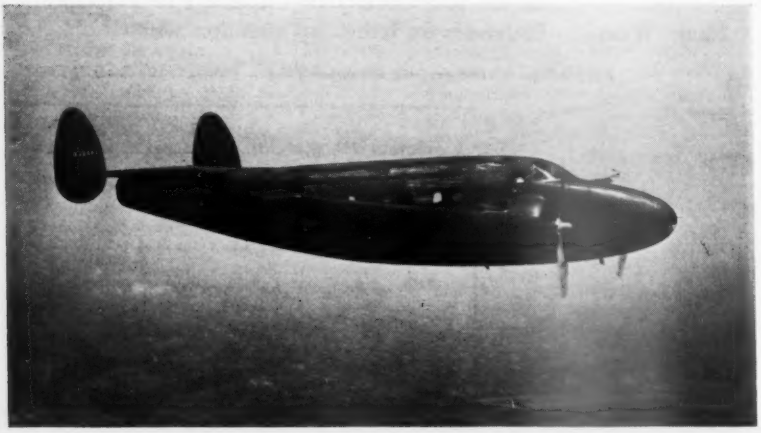
• **The Glenn L. Martin Company. . .**A $16,000 scholarship grant has been given to Drexel Institute of Technology. It will be used for scholarships to students who will participate in Drexel's cooperative plan of education. Similar scholarships have been established at Georgia Institute of Technology and Massachusetts Institute of Technology. The Martin company was one of 35 firms that recently received the Drexel Citation of Recognition for extended participation in that school's program of cooperative education.

• **The Glenn L. Martin Company and Reaction Motors, Inc. . . .**The Martin-built Navy Viking No. 11 established a new world's altitude record for single-stage rockets when on May 24 it climbed to 158 miles above the earth's surface. Three of the earlier Vikings, Nos. 7, 9, and 10, had reached an altitude of 136 miles. All of the Vikings were designed and built by Martin for the Navy for the purpose of exploring altitudes previously closed to scientific research in cosmic rays, atmospheric composition, radio propagation, photography, and spectroscopy. Viking No. 11, like its predecessors, was powered with a rocket engine manufactured by Reaction Motors. This one is a single-chamber rocket engine that produces 20,000 lbs. of thrust at sea level and operates on liquid oxygen and a mixture of alcohol and water.

• **North American Aviation, Inc. . . .**A $4,500,000 wind tunnel capable of speeds ranging from 400 m.p.h. to Mach No. 3 is now under construction. The tunnel's structural parts are being designed and engineered by Pittsburgh-Des Moines Steel Company under the terms of a $4,000,000 intercompany agreement. The remaining $500,000 of the total cost is the amount estimated by North American for the acquisition of building property and for the construction of buildings to house the testing equipment. It is hoped that the new developmental facility will be near North American's F-86 Sabre and F-100 Super Sabre assembly lines at the Los Angeles (Calif.) International Airport. The company says that this will be the nation's largest intermittent blow-down wind tunnel, with wind speeds being produced by compressed air rushing from a series of large-volume storage spheres at selected intervals. Each test will be less than a minute in duration. To facilitate the regulation of air speeds at subsonic, transonic, and supersonic levels, an adjustable nozzle, a transonic chamber, and a variable diffuser will be placed in a series in the tunnel's throat. The test chamber will be 17 ft. long and 7 ft. sq. and will handle a plane or a missile model with a wing span of about 4 ft. The facility is expected to be completed in March of 1956. . . .The last "F" model of the F-86 Sabre rolled off the company's Los Angeles assembly line on May 27 for delivery to the Air Force. The first production F-86F was flown and accepted by the Air Force on March 19, 1952. Other models of the Sabre, the "D" and the "H," are being manufactured at Los Angeles and Columbus, respectively. The area in Los Angeles vacated by the conclusion of the F-86F contract is to be used for F-100 Super Sabre production and is being retooled for that purpose. . . .The twenty-thousandth fighter aircraft to be designed and built by North American was delivered on May 14. This particular airplane was an FJ-3 Fury jet fighter for the U.S. Navy. North American reports that it has built more than 50,000 airplanes of all types.

• **Northrop Aircraft, Inc. . . .**A new computer, called the Quadratic Arc Computer and nicknamed "Quac," has been designed and built by Northrop under contract to the U.S. Air Force. The computer measures 5 ft. in length by 40 in. in width by 33 in. in height and is said to be capable of programming accurately over 20 separate flight operations simultaneously. With its 6,000-plus electronic parts, it can make 5,000 calculations per second and can store up 2,600 digits in its memory system. . . .Additional Northrop personnel are being transferred to the firm's Palmdale (Calif.) Airport Flight Test Facility, augmenting the 250 persons already there. The 250 are engaged in preliminary flight testing operations, while those being transferred are concerned with radar operations, functional flight testing,

The first production Learstar to come out of Lear Incorporated's plant in Santa Monica, Calif., is shown while over Los Angeles Harbor during its initial flight on May 10. The Learstar in this photograph is covered with a zinc chromate coating. Further details concerning the new Learstar may be found in the Lear item in Corporate Member News.



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We believe the counsel of our engineering specialists can contribute appreciably to the safety and dependability of today's most advanced aircraft and those you are now developing. Your inquiry is invited.

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painting, and stripping. The transfer of these employees to Palmdale is being accomplished in three moves and on a gradual basis. The first is a large-scale movement of radar personnel and equipment which was expected to have been completed by July 19. The final shift of radar operations is being made by August 30. Flight, paint, and strip personnel will make the transition to Northrop's jet testing base by November 30. The number of Northrop personnel at Palmdale is expected to reach over 1,100 by November of this year.

• **Pan American World Airways, Inc. . . .** The three new DC-6A air-freighters were placed into service on May 21 on Pan American's scheduled North Atlantic all-cargo route between New York, Shannon, London, Amsterdam, and Frankfurt. These aircraft have a gross cargo space of 5,000 cu.ft. and are capable of transporting up to 26,000 lbs. of freight. The ships are fully pressurized and are equipped with automatic temperature and humidity controls which operate on the ground as well as in flight. The addition of these DC-6A's to the all-cargo fleet increases by approximately 50 per cent Pan American's available cargo space on the North Atlantic.

• **The Parker Appliance Company. . .** According to a recent company release, the Engine Accessories Division has developed an entirely new-type variable-area fuel nozzle to minimize the current fuel-system problems facing air-frame manufacturers. Announced performance features of this new nozzle are: (1) ability to handle contaminated fuels, (2) excellent atomization leading to substantially reduced specific fuel consumptions, particularly at high altitudes, (3) maintenance of full-fuel manifold ensuring quick, positive starts, even at low engine speeds, and (4) accurate nozzle metering eliminating the need for any expensive fuel-system flow dividers and resulting in greatly reduced dispersion of burner temperatures. As the outside shape and size of the nozzle body can be modified and a variety of spray sheaves, shapes, and angles are possible, the nozzle can be made to meet specific customer requirements over a broad range of operating conditions.

• **Radioplane Company. . .** Whitley C. Collins, who was elected President of Northrop Aircraft, Inc., continues as President of Radioplane. There are, however, certain changes in the company management. They are: William Larrabee, formerly Vice-President and General Manager, now Executive Vice-President; Ferris M. Smith, formerly Vice-President—Engineering, now Assistant to the President and in charge of foreign sales; and M. W. Tuttle, formerly Vice-President—Military Relations, now Vice-President—Operations.

• **Republic Aviation Corporation. . .** On May 12, the U.S. Air Force and Republic Aviation announced the first flight of the Republic YF-84J at Edwards AFB, Calif. The aircraft that made this flight is the first of two YF-84J's ordered for experimental purposes. The "J" model, the latest in the Thunderjet-Thunderstreak series, is powered by the J-73 turbojet engine, manufactured by General Electric Company. The air-intake duct, fuselage, dive-brake area, and internal systems of the YF-84J have been redesigned. . . . Walter G. Bain, who joined Republic in September, 1953, as Executive Assistant to the President and who last January was made a Vice-President, has been appointed Vice-President and General Manager. Mundy I. Peale, AMIAS, President of Republic, formerly handled both the presidency and general managership.

• **Ryan Aeronautical Company. . .** The company's Electronics Division is developing a self-contained air-borne helicopter hovering device. This developmental work is being done under a contract from the USN BuAer's Airborne Equipment Division.

• **Seaboard & Western Airlines, Inc. . . .** A flight and ground training school for crews to be assigned to the Super Constellation air freighters has been established by the company. Four of these 18-ton-capacity freighters are being delivered this summer to Seaboard & Western.

• **Shell Oil Company. . .** It was announced recently that Shell had developed an improvement in pumping systems of aviation fuel trucks and that plans for it are being made available without cost to the oil and aviation industries. The major advantage of the new system is that it uses light, collapsible hose. The improvement is based upon a new use of the jet eductor which in Shell's adaptation essentially replaces the conventional four-way valve. The jet eductor, Shell reports, permits a pumping rate of some 225 gal. a min. in fueling operations with a single hose as compared with a pumping rate of 160 gal. per min. possible with the older systems. Adaptation of the jet eductor to pumping systems is said to have effected a saving of some $3,000 per refueler unit.

• **Solar Aircraft Company. . .** A new brochure, "Ceramic Coatings for Protecting Metals," has been issued by the company. This booklet covers the uses and properties of Solaramic coatings, a family of proprietary ceramic coatings specially designed to protect high- or low-alloy steel fabrications from heat or corrosion. The publication furnishes a check list of the properties of these coatings under high temperature, medium temperature, and corrosive service. It also includes a listing of the basis metals to which Solaramic coatings can be applied for various service conditions and a check list of considerations in designing metal parts that are to be ceramic coated. Copies of this new ceramic-coating booklet are available from Solar's Department 701 in San Diego.

• **Sperry Gyroscope Company, Division of The Sperry Corporation. . .** The Sperry Corporation has announced that the Sperry Electronic Tube Division has been formed and that a new $600,000 facility for the development and production of electronic tubes will be built on a 47-acre site 3 miles out of Gainsville, Fla. This 60,000-sq.ft. plant has been leased by the corporation for a period of 6 years. As the first product, the Sperry Electronic Tube Division will manufacture model SAL-39 klystron tubes in quantity for use in a military air-navigation system developed by the U.S. Navy.

• **Summers Gyroscope Company. . .** A new position servo actuator, Model 205, is now in production at Summers and is offered in two basic versions: one for piloted aircraft and the other for pilotless aircraft. Each contains a drive motor, radio-noise-suppression network, low-inertia precision gear train, and a follow-up potentiometer. The piloted model contains an overload and disconnect clutch, and the pilotless model has an overload clutch. These elements are housed in a sealed waterproof case that measures 5.75 by 3.75 in. for both the piloted and pilotless versions. The former, however, weighs 4.75 lbs., while the latter weighs 4.25 lbs. Output capstan of the instrument is free to rotate 360°. Model 205 has a torque-to-inertia ratio of 200,000 rad. per sec.^{2} and an acceleration time constant of 10 millisec. Maximum continuous torque at 28 volts is 200 in.lbs. Additional torque outputs are available to customer requirements. Equivalent motor stall torque at 28 volts is 1,200 in.lbs. Operating voltage range is from 5 to 35 volts. Operating current is 0.4 amp. with no load and an additional 0.1 amp. per in.lbs. of load. . . . An air-borne reference gyro that accelerates to operational control in 10 sec. has been announced. Known as Model 221, it is currently employed in a ground-to-air supersonic missile and is to be used as a reference element in an air-to-air missile. This production gyro is designed to withstand extreme acceleration and shock up to 60*g*. It will operate successfully, without excessive drift, during vibration up to and including 10*g* at 1,500 cycles per sec. Model 221 reference gyro is available for use in aircraft and target drones.

• **Western Gear Works. . .** A new rotary actuator, designated as Model 1524, has been announced. It was initially developed for aircraft use in opening and closing camera doors, wing-tip tank release, and similar operations requiring an actuating mechanism; however, it also has electronic, automatic control, and original-equipment application potential. The specifications of this new rotary actuator are given as follows: 110-volt single-phase 400 cycle reversible motor with brake; 96:1 ratio; 10,600-r.p.m. input; 12,000-cycle 110-r.p.m. output developing 500 oz. in. of torque. Stopping tolerance is plus or minus 10°. Thermal protection is provided.

• **Westinghouse Electric Corporation. . .** The Engineering Department of Westinghouse's Aviation Gas Turbine Division has been reorganized into six new divisions. The new departments and their managers are: Advanced Development Division, G. W. Hardigg; Preliminary Design Division, A. H. Redding; Development Engine Division, H. B. Saldin; Production Engine Division, P. G. DeHuff; Experimental Operations Division, T. A. Daly; and Administrative Control and Services Division, C. S. Cody. Mr. Daly, who temporarily heads up the Experimental Operations, was named to the newly created position of Executive Engineer. The managers of the various new departments will report to R. L. Wells, who was appointed Assistant Chief Engineer for Aviation Gas Turbine Division. Both Mr. Wells and Mr. Daly report directly to

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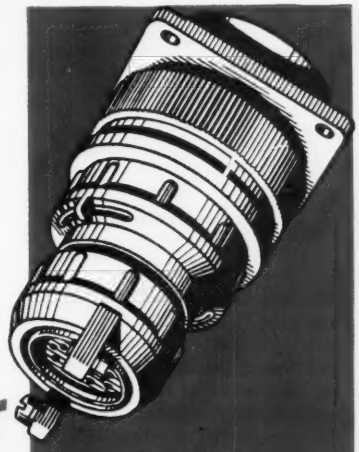

The challenge to protect sensitive airborne electronic circuits from thermal shock, surface condensation and extreme vibration has been successfully met by Bendix engineers in this new spaced grommet "E" connector.

This connector is not only designed for performance, but is also engineered for your production needs. The open space in the solder-well area provides ample room for all assembly and soldering operations. Moisture-proofing is accomplished without the use of potting compounds, permitting completely serviceable aircraft harness installations.

These features are all accomplished with no appreciable increase in weight over an AN-A/B connector with a cable clamp.

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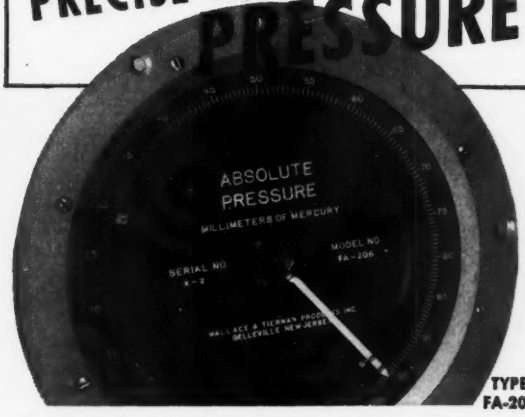

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W&T Precision Absolute Pressure CONTROLLER . . .
. . . coupled with electronic relay unit (not shown)
To Control the Absolute pressure of closed systems within narrow limits.

. . . Ranges: 0—20 mm through 800 mm Hg absolute in six ranges
. . . Accuracy: 1 part in 300 of full scale
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A-104

Allan Chilton, FIAS, AGT Division Chief Engineer. . . .Donald C. Burnham has joined Westinghouse Electric Corporation as Vice-President in charge of Manufacturing. He succeeds T. I. Phillips who retired after 39 years of service. Mr. Burnham was formerly with General Motors Corporation.

IAS Sections

Boston Section

E. L Dashefsky, *Secretary*

The third meeting of the 1953–1954 season of the Boston Section was held on April 6. Preceding the meeting at the Massachusetts Institute of Technology, dinner was served at the Smith House. Approximately 20 members were present for dinner, and 125 members and guests at the meeting.

The Chairman, Mr. Morrison, welcomed the Boston University Student Branch, which has recently been formed. M. Maller introduced the guest speaker, Ernest G. Stout, Staff Engineer for Convair Division of General Dynamics Corporation. Mr. Stout has for years been the foremost proponent for water-based aircraft and was honored by the IAS with The Sylvanus Albert Reed Award for 1953 for his contributions in the field of water-based aircraft.

Mr. Stout's paper was entitled "Development of High-Speed Water-Based Aircraft."

"Through the use of the dynamically similar model research technique, it has been possible to assimilate modern advances in power and aerodynamic refinement into the design of water-based aircraft that have completely closed the gap in relative speed between the seaplane and the landplane.

"With deficiency in performance overcome, the water-based aircraft promises to effect radical revisions in military concepts and strategy. Elimination of the time consuming preparation of costly airstrips minimizes logistic support, enhances the element of surprise, increases the fire power that may be brought to bear on remote targets, and reduces attrition to a point that could prove to be the margin between success or failure in a fluid war where mobility and dispersion are paramount.

"Water-based air transport ruled the world's lanes of aerial commerce for years, due to the ability to provide unmatched economy, comfort, versatility, dependability, and, above all, safety. Lacking one essential ingredient—speed—these other inherent qualities were compromised in favor of the faster landplane. Development of the high-speed blended hull has made possible a water-based jet transport that meets the requirement of modern commercial aircraft speed without compromise to any of the established inherent advantages of water-basing. Of even greater significance is the possible solution the use of water-based jet transports may provide for the critical problems of air traffic control and congested terminal facilities which are posing insurmountable obstacles to the mass utilization of jet transportation."

A film was shown of the Sea Dart during take-offs and landings. A question-and-answer period for approximately 30 min. followed this interesting and enlightening presentation. The meeting adjourned at approximately 10:00 p.m.

Chicago Section

L. W. Sims, *Secretary*

On Wednesday, May 19, the Chicago Section held its Annual Meeting at the Officers Club of the Glenview Naval Air Station. This was the fifth year in which this Annual Meeting was held at Glenview, and the policy of combining a social program for the benefit of wives and guests was also continued with great success. The primary object of the Annual Business Meeting is the election of Officers and Advisory Board for the new year.

At 5:30 p.m., members and guests arrived for a tour of the Air Station. Navy buses were provided for this function, and three members of the Air Station staff, Comdr. S. B. Berrey, Lt. Comdr. R. A. Schram, and Lieutenant Nelson, conducted the tour. The tour included a trip through the training department and the maintenance hangars, and included an inspection of an F9F-7 Cougar airplane which had sections of the fuselage removed to show the engine installation. An armament exhibit was also on hand for review.

At 6:30 p.m., the group assembled in the Colonial Room for cocktails, and at 7:30, dinner was served to 140 members and guests in the main dining room.

After dinner, the business meeting was opened by Chairman Alfred F. Stott who first introduced the guests at the speakers table and extended thanks to the Commanding Officer of the Station for making the facilities available to the group. Mr. Stott then introduced Comdr. T. W. McKnight, Executive Officer, who greeted the group in behalf of Capt. Ford Taylor, Commanding Officer. Commander McKnight heartily greeted the group and described the organization and function of the Air Station.

Chairman Stott then got the business of the evening underway by explaining that the proposed slate of officers and Advisory Board had been mailed to all members prior to the meeting with the request that the names of any further nominees be mailed to Secretary Lee Sims, but that none had been received. Dr. H. L. Hull, Chairman of the Nominating Committee, then read the list as proposed by his committee. A motion was made and seconded that the proposed slate be adopted, and as a result of a hand vote of the members, it was voted in. The officers for the year, 1954–1955, are as follows: Chairman, Richard A. Schram; Vice-Chairman, J. W. Pocock; Secretary, L. W. Sims; and Treasurer, H. L. Wackelin. The Advisory Board consists of K. L. Burroughs, R. O. Britten, R. N. Du Bois, H. V. Hawkins, A. F. Stott, H. L. Hull, T. C. Linnert, and B. M. Vinicky. The Representative to the Nominating Committee for Area Councilors is Lt. Col. D. J. Smith, ANG.

Mr. Stott congratulated the new officers and introduced them to the group. He then turned the meeting over to Mr. Schram who announced that two films, *Fighter Photo Story* and *Away Boarders*, were to be shown. These two films were much enjoyed by all present. After their presentation, the meeting was adjourned.

Hagerstown Section

George W. Westphal
Secretary-Treasurer

The annual spring dinner meeting of the Hagerstown Section of the IAS was held at the Fountain Head Country Club on Wednesday, May 12. Approximately 93 members and guests were present.

R. A. Darby, Chairman, opened the meeting. He reminded the membership of the closed meeting to be held by the Baltimore Section on May 20 and to which those with the required security clearance were invited to attend.

Mr. Eisiminger reported that the final program of the current season is to be a field trip to Aberdeen Proving Ground on June 12.

Mr. Darby then introduced Louis Fahnestock, Director of Engineering for Fairchild Aircraft Division, who in turn introduced the guest speaker, Grover Loening, internationally known Aircraft Pioneer, Pilot, Engineer, Aeronautical Consultant, and a Director of the Fairchild Engine and Airplane Corporation.

Mr. Loening presented a most interesting account of early experiences in the aeronautical engineering field. He carried these experiences and trends to the present and then projected them into the future. He emphatically pointed out

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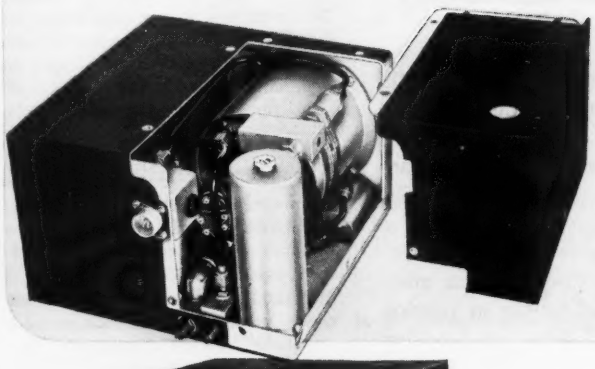

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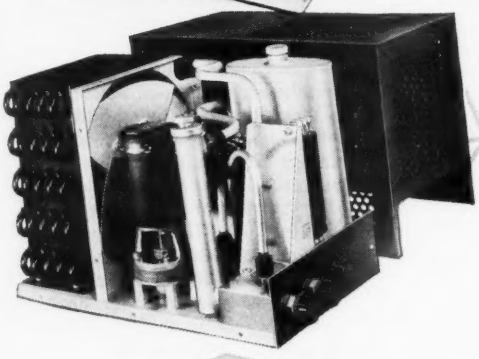

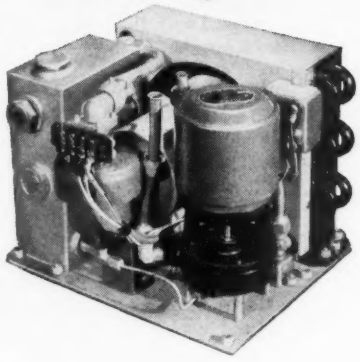

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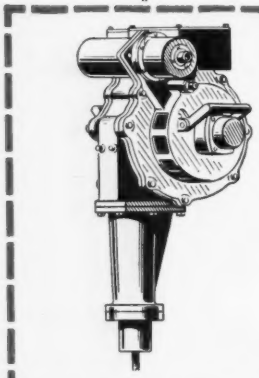

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how current trends are blotting out development in the field of private flying and how the development of new weapons and methods of warfare are affecting the design of aircraft. Mr. Loening concluded his talk by showing a film on water-based aircraft.

Los Angeles Section

Evert C. Hokanson, *Secretary*

"Engineering Tomorrow's Air Weapons" requires qualified, experienced supervisory personnel functioning in a pyramid type of organization. Such is the opinion of Edgar Schmued, Vice-President in Charge of Engineering, Northrop Aircraft, Inc. His talk was given at the May 20 Dinner Meeting of the Los Angeles Section before an audience of over 250 members and guests. Mr. Schmued is considered one of the country's foremost aircraft designers and spoke from a background of many years' experience. It is understood that he has consistently practiced the principles given in the following résumé.

Key personnel who have the ability to develop superior designs are of prime importance. The most effective use of the abilities of these individuals can only be made when they function within the framework of a good organization. Top men should be completely free to handle the broad issues and should not be bogged down or even permitted to dig into small details. The best men are empire builders, but if company management does not control and properly channel these energies and abilities, the organization will begin to deteriorate.

The supervisor, at any level, has but one problem—that of providing the men under him with all the help needed to do the job, whether it be man-hours or technical information from higher or parallel echelons. He should spend sufficient time with his men, especially the new men, so they fully understand what is wanted and needed. Men do not like to loaf and will not do so when provided with the tools and information necessary to do their jobs. He should treat them well and show respect for their abilities. Every man has the right to be respected, if he is in the right job for him and for the company. Men will cooperate, if told the "why" when instructions are given. When a mistake is made, and all of us do make mistakes, the only question should be "how do we correct it?"

Engineering organizations must be made more efficient as the schools cannot provide for the present requirements of industry. When expansions are necessary or new groups are brought in, such as occurred when aircraft companies started guided missile work, experienced personnel with knowledge of the organization and procedures must

be mixed with the new people to help them become members of the team.

Big engineering departments can be efficient, but the important idea to keep in mind is not how big can the department grow, but how small it can be kept and still do the job at hand. This can be done by properly delegating responsibility accompanied by adequate authority so that each supervisor can make the decisions for his group. The extent of responsibility and authority for every supervisory position must be covered by the job description in clear and concise details. This will make a happy, hard-working, efficient team which will make "Tomorrow's Air Weapons" the best in the world.

Warren T. Dickinson, Vice-Chairman of the Los Angeles Section, presided. He introduced a number of distinguished guests including: Dr. Walter S. Diehl, Consultant; Dr. Walter O. Mischke, Director of United Technical Institute in West Germany; C. Thomas Reid, Cal-Aero Technical Institute; Dr. William F. Ballhaus, Chief Engineer, Northrop Aircraft, Inc.; and Leonard Goodman, Chairman of U.C.L.A. Student Section. George Mellinger, General Chairman of the Program Committee, introduced Mr. Schmued.

▸ At the May 13 Specialist Meeting, Robert A. Bailey, Division Engineer, Lockheed Aircraft Corp., presented a paper entitled "The Application of Operation Research Techniques to Airborne Weapons System Planning." Mr. Bailey described the techniques of operations research which have shown promise of improving the basis on which basic decisions are made for design and implementation of future weapon systems. With the help of slides, he ably presented the characteristics of the analyses and methodology used and followed this by an evaluation and the uses of the results obtained. L. Eugene Root introduced the speaker; Richard Boyles presided.

▸ L. S. Michels, Bendix Computer Division, Bendix Aviation Corporation, presented a paper entitled "Theory of Operation of the Digital Differential Analyzer and its Application to Aeronautical Engineering Problems" at the May 27 Specialist Meeting. A short introduction to the theory of the digital differential analyzer was given. This included the definition of an integrator, the description of the time-sharing principle, and the method of addressing, along with other facts concerning the internal operation. Mr. Michels described the programing and coding of the problems for entry into the computer. The results of the demonstration problem as obtained from the computer were shown on slides. More complex problems, the associated programming and coding, were also discussed. Gerald Thomas, Chairman of Specialist Meeting Committee, presided and introduced the speaker.

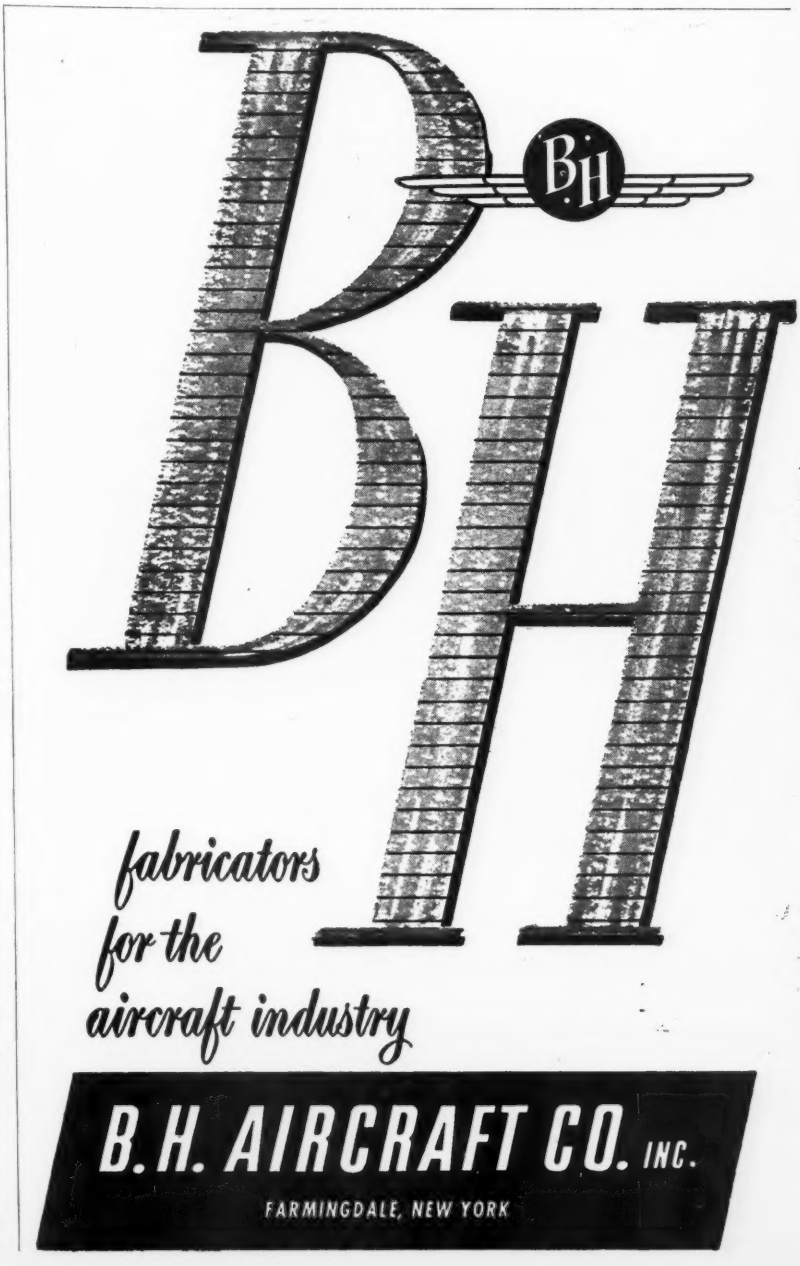
St. Louis Section

J. H. Meyer, *Chairman*

The St. Louis Section has had several changes in officers and committee chairmen during the 1953–1954 year. These changes are as follows:

The Vice-Chairman, Allan McCoy, Sverdrup & Parcel, resigned, and as of May 19, no successor had been appointed. The Treasurer, Paul R. DesJardins, Army Aviation Field Service, resigned to take a job with North American. His successor, Lt. Milton A. Silveira, occupied the position from January through April and was then transferred to a post in Japan. A new Treasurer, Robert A. Killoren, McDonnell Aircraft Corporation, took over as of May 18.

Larry Edwards, Chairman of the Program Committee, resigned from McDonnell to enter the kitchen-furniture field and also resigned the Program Committee Chairmanship. His successor is Frederick H. Roever, Administrative Assistant, Helicopter Division, McDonnell.



Innes Bouton took a job at Northrop Aircraft, Inc., and resigned the Chairmanship of the Publicity Committee. The new Chairman of that group is Allen H. Madrick, Helicopter Design Engineer, McDonnell.

San Diego Section

H. C. Matteson
Corresponding Secretary

The San Diego Section held its second annual spring dance the evening of May 8. The 230 Institute members and guests danced to Francis Leonard's orchestra from 9:00 p.m. to 1:00 a.m. A buffet supper was served throughout the evening.

▶ On May 11, the San Diego Section offered a "movie nite" to the membership. The featured film was the United Aircraft Corporation's *We Saw It Happen*, which summarizes the development of aviation to its present state by relating the more significant aviation events that have occurred during the past 50 years. This type of meeting was an innovation at San Diego, and its appeal to the membership was demonstrated by the fact that over 200 people were in attendance. In view of their apparent popularity, more "movie nites" are being planned for the future.

▶ A dinner meeting was held at the San Diego IAS Building on May 27. The speaker for the evening was T. G. Lanphier, Vice President, Convair Division of General Dynamics Corporation. Mr. Lanphier's subject was "Weapons Systems In The H-Bomb Era."

The speaker discussed the weapons system concept generally and illustrated the extreme need for adequate weapons systems in these times. He emphasized the effect that a strong military position, particularly in long-range striking power, had on the diplomat's bargaining position in international politics. In this connection, he stressed the vital necessity for maintaining technical superiority in all fields of weapons development. Mr. Lanphier's talk was thoroughly appreciated by an audience of approximately 70 members and their guests.

Seattle Section

Russell B. Light, *Secretary*

A dinner meeting of the Seattle Section was held on March 17 at the Sand Point Naval Air Station Officer's Club. A social hour preceded the dinner.

The guest speaker was W. C. Lawrence, Director of Development Engineering for American Airlines, Inc.

Mr. Lawrence presented American Airline's thinking on future transport aircraft with a comparison of internal-combustion-, turboprop- and turbojet-powered transports. He prefaced his talk with the following qualifying statements: (1) his analysis applies to initial usage of turbine types in commercial operation and to planes to be used on first-class transcontinental service; (2) the analysis was made before viewing the "Boeing 707 Stratoliner"; and (3) American Airlines strives to maintain as fast a service as possible.

In his study, Mr. Lawrence used the operating cost per mile as a basis of comparison. The "paper" jet types were compared with the DC-6 airplane. Both the turbojet and turboprop costs per mile were, as expected, higher than the conventional airplane. However, except for the turboprop in the medium and short ranges, the advantage was not clearly indicated for either jet type. A study using a by-pass engine indicated that a design utilizing this type of engine offered better commercial air-transport potential through: (1) propulsive efficiency greater than turbo-jet; (2) augmented thrust at low speeds; (3) reduced noise level; and (4) avoidance of special runway requirements. The major disadvantages were given as: (1) propulsive efficiency less than turboprop; (2) a weight increase; and (3) this type not currently under development.

Mr. Lawrence's talk stimulated a great deal of interest as evidenced by questions from the audience.

Seattle Branch, Historical Associates

C. A. Bosserman, *Secretary*

On April 14 at the Museum of History and Industry, the Seattle Section of the IAS formed the Seattle Branch of the Historical Associates of the IAS. Approximately 100 persons were present.

Peter M. Bowers, of the Boeing Engineering Service Department, gave an interesting talk illustrated with 50 specially made slides. The slides and his talk, "So You Think That's New," compared supposedly new features and arrangements appearing on recent aircraft with similar designs appearing on some early airplanes.

G. E. (Nick) Ledbetter, Chairman of the Seattle Section of the IAS, with the assistance of E. W. Robischon, IAS Western Region Manager, explained the sponsorship and assistance the Seattle Section and the national IAS would be able to grant the Seattle Branch of the Historical Associates, and its relationship to the regular IAS.

Mr. Ledbetter then appointed the following temporary officers for the Historical Associates: Peter M. Bowers, Chairman; Ben Carter, Vice-Chairman; Alvin J. Jarvis, Program Chairman; and Charles A. Bosserman, Secretary. They will serve until the Branch is able to elect regular officers concurrently with the election of the regular Section officers next fall.

Texas Section

John H. Boucher, *Secretary*

The regular monthly dinner meeting for May was held at 7:45 p.m., Friday, May 28, in the private dining rooms of the Fort Worth International Airport. The Texas Section was proud to have Major Gen. J. B. Montgomery, Commanding General of the Eighth Air Force of the Strategic Air Command, as guest speaker presenting "Strategic Air Power, Yesterday and Today."

At the conclusion of an excellent dinner, Douglas G. Andreoli, Section Chairman, opened the meeting by making a

Shown at the Texas Section's May 28 Dinner Meeting are Major Gen. J. B. Montgomery, USAF, Commanding General of SAC's Eighth Air Force, who was the dinner speaker, and Section Chairman Douglas G. Andreoli, flanked by four past Chairmen of the Texas Section. From *left to right* are: W. A. Pitman, E. W. Fedderson, General Montgomery, Mr. Andreoli, H. Johnson, and O. N. Thompson.

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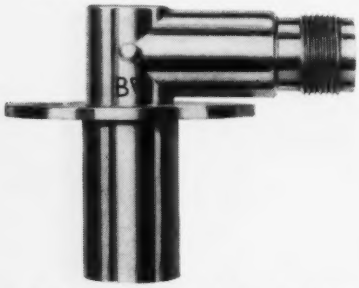

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presentation of gold keys to all past Chairmen of the Texas Section residing in the area. Mr. Andreoli briefly narrated the accomplishments of each of the past Chairmen as he presented keys to the following: E. Fedderson, Assistant Project Engineer, Convair, Chairman, 1944; Oscar Thompson, Structures Project Engineer, Convair, Chairman, 1945 and 1946; Harold Johnson, Convair, Chairman, 1946–1949; and W. A. Pitman, Staff Engineer, Chance Vought Aircraft, Chairman, 1949 and 1950. Mr. Andreoli in closing made an announcement on the forthcoming social to be held at the Dallas Naval Air Station on 25 June, 1954.

After a short recess for leg stretching and room rearrangement, H. Teeter, Convair, Co-Chairman of the Program Committee, presented General Montgomery. General Montgomery, a youthful and dynamic looking man, introduced himself as a bomber pilot but pointed out that his organization, the Strategic Air Command, included fighter squadrons for bomber protection from enemy aircraft. In commenting on the future outlook for SAC and the Air Force, General Montgomery highlighted the significant problem of man-power turnover, pointing out that in the past year a 65 per cent turnover occurred. The Air Force vitally needs men of prestige to operate the new and complex equipment efficiently in global operations.

General Montgomery compared the pre-World War II bomber aircraft with present-day bomber aircraft—velocities of 120 m.p.h. as compared to the modern-day 600 miles per hour; altitudes of from 12,000 to 15,000 ft. as compared with the 40,000-plus ft. possible today; and the 30 cal. armament vs. the present-day 20 and 30 mm. He cited as illustration of the advances made the recent round-the-world nonstop flight of a B-50 bomber made possible through inflight refueling at four C-97 tanker stations. He mentioned that a B-47 could do it today in only 46 hours with similar inflight refueling assistance. He pointed out that by present day standards England was only 5 hours away from the United States; North Africa, 7 hours; and Japan, 8 hours. Further emphasizing the global scope of SAC, General Montgomery stated that the master control room of the Eighth Air Force in Fort Worth was constantly in contact with SAC bombers throughout the world by direct radio.

General Montgomery mentioned the arbitrary decision to drop the first nuclear weapons on Japan as opening a new era in the striking power of strategic air power. He mentioned as justification for having used the A-bombs, the later findings that Japan was ready, waiting, and well prepared for any enemy invasion; and that somehow

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Japan had obtained information as to the exact points of intended invasion. In the 9 years since the release of the first A-bomb in New Mexico, tremendous strides have been made resulting in the perfection of the H-bomb, which is described with a relatively new term of power, the megaton, for comparison with the equivalent amount of TNT. To emphasize further the awesome power of the H-bomb, General Montgomery stated that the equivalent power in 2,000-lb. bombs would stretch from Dallas to Boston!

General Montgomery pointed out the well-known fact that the advantage in any encounter is always with the attacker, since he can establish the tactics, i.e. speed, altitude, time, location, etc. A startling fact, related by General Montgomery, is that there is no absolute defense against a bomber force. During the World War II, the losses suffered during strategic bombing of Germany usually ranged under 10 per cent and when the figure exceeded 20 per cent, the attacking forces became concerned. Nonetheless, a good static defense, while relatively ineffective, imposes a significant additional expense on the enemy by way of additional requirements. Through this means, we can "keep the enemy honest," but we cannot stop him. For mutual advantages, SAC constantly practices penetration of all parts of the U.S. air defense. The present state of the art in brief is such that, while current defense measures may cause losses to rise significantly, penetration can still be attained!

General Montgomery described the tremendous ground power of the communist nations by stating that the Russians currently have approximately 225 ground divisions in service; this was compared with the very maximum bottom-of-the-barrel effort of the United States to raise 97 divisions during World War II! With the Chinese and other Iron Curtain nations, it is estimated that communist ground forces could approach 1,000 divisions! General Montgomery, along with many others, considers the A- and H-bomb potential of the United Nations the primary deterrent to communist aggression. Other interesting A-bomb sidelights learned from General Montgomery were (1) that Nagasaki was a secondary target and was bombed when the primary target was found to be weathered in and (2) that the Japanese government had started to end the war almost a year earlier after the fall of Saipan, but this had been prevented by the political power of the military.

General Montgomery went on to describe the growth of strategic air power. During World War I, it was just a faint glimmer, but through the valiant efforts of the Mitchells and the Arnolds, this glimmer grew to be a potent force whose

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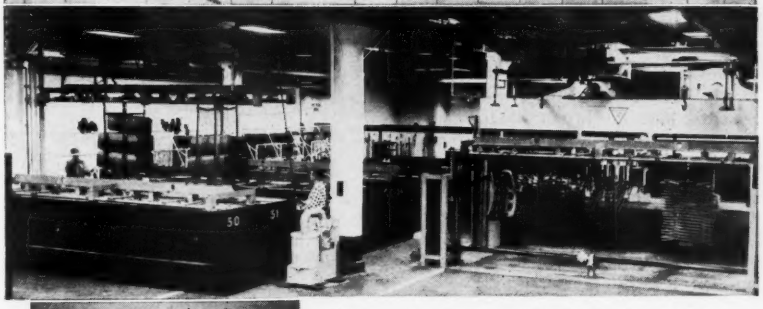

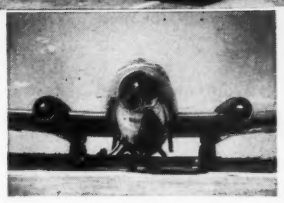

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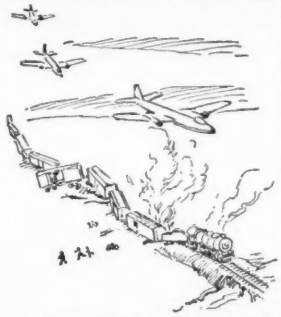

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effectiveness had been proven during World War II. At the time of Pearl Harbor, only 600 military airplanes were fit for combat. The 97th Bomb Group was one of the earliest to be called into active combat, and in August, 1942, participated in air raids on France. Unfortunately, however, these earlier aids were only operational training for the Luffwaffe! Roosevelt, Arnold, money, and time built the U.S. Air Force during World War II. A larger and more powerful air force in being prior to World War II might have deterred Hitler from his plan of world conquest.

Strategic air bombardment of Germany during World War II was next outlined by General Montgomery. The combined air forces of the Allies were dropping close to 250,000 tons of high explosives per month at the end of the war. All in all, 1,500,000 sorties were flown with 2,500,000 tons of high explosives dropped at a cost of 22,000 bombers and 158,000 airmen! This action, however, produced complete economic collapse of the primary German industrial cities and a heavy loss of civilian housing and lives. It took 3 years to bring this power to bear against Germany with only 17 per cent of the above figures being accounted for during the first 2 years and the remaining 83 per cent in the last year! In strategic air bombardment of Japan, 33,000 B-29 sorties were flown and 100,000 tons of bombs dropped, with 485 bombers and 3,000 crewmen being lost. It is significant and a tribute to the Air Sea Rescue groups that 600 airmen were saved from the sea during the raids on Japan. Some interesting details were brought out about these raids on Japan. It took on an average of $1^1/_2$ hours to drop the total tonnage over a given target. Prior to the A-Bomb release, a systematic program was carried out for the fire-bombing destruction of major Japanese cities. Civilian populace were always warned in advance by leaflets of the pending raids, and the maximum attrition reached a total of 48 cities destroyed per month! All in all, some 330,000 Japanese people were killed from strategic bombing, including the two A-bombs on Nagasaki and Hiroshima. It is a significant point that, in this modern era of such tremendous strategic bombing power, the use of nuclear weapons has made it imperative that each and every aircraft be thoroughly respected.

General Montgomery described the Strategic Air Command as being made up of three Air Forces: The Eighth, with headquarters at Fort Worth; the Second; and the Fifteenth. These forces are made up of heavy bombers, tankers, and fighters. The primary bomber aircraft have been the B-50 and the B-36 which will eventually be replaced with B-47's and B-52's. The tankers are C-97's, and the fighters are F-84 Thunderjets. Throwing bouquets at Convair, General Montgomery stated that the B-36 airplane, more than any other, has played an important role in winning the current peace.

General Montgomery described the basic SAC mission as being the conduct of strategic attack. Bomber crews in SAC are selected and qualified and are kept together as a unit in a state of constant readiness. All crews have preestablished points of assignment and attack in the event of any emergency. The average SAC airplane commander is 32 years old, has had 9 years of Air Force experience, accumulated 3,800 hours of flying, and holds the rank of Captain or Major. The accident rate in SAC has dropped from 60 to 18 major accidents per 100,000 hours of flying during the last 5 years. Most of the practice bomb runs made on various cities in the United States are accurately checked by radar plots. Crew training is rigid and, in recognition of having qualified on a SAC crew, a system of spot promotions is used wherein every man carries 1 grade higher than his normal grade.

General Montgomery explained that, despite some information to the contrary, strategic bombers in Korea were regularly outnumbered by MIG's by 10 to 1, but recorded losses show only one airplane in every 1,000 raids on North Korea! SAC bases are thoroughly dispersed over the entire continental United States in such a way that it is felt to be impossible for any enemy force to begin to knock out all SAC bases without devastating retaliation. In line with further emphasizing the tremendous striking power of SAC, General Montgomery explained that two SAC wings, made up of 30 to 40 airplanes per wing, in a matter of a few days could produce the effect of the entire strategic air bombardment of Germany during World War II!

The entire audience of over 100 members and guests were thoroughly impressed with General Montogomery's description of strategic air power, and with this dynamic and able man who shoulders the important responsibility of controlling a large portion of this power of SAC.

Student Branches

Academy of Aeronautics

Richard M. Woessner
Corresponding Secretary

At the meeting of April 29 at which 46 members were present, a report was given by M. Lombardo, Chairman of the Meetings and Papers Committee. In this report, Mr. Lombardo advised the group that, starting with the May 27 meeting, speeches would be delivered by members of the senior class.

Chairman Felix Curasi then opened a short discussion concerning our forthcoming field trips to the NACA Langley Aeronautical Laboratory and to Republic Aviation. The Langley field trip is scheduled for June 11, and the Republic field trip is planned for May 8.

The McDonnell Aircraft Corporation film, *Little Henry*, was shown and brought the meeting to a close.

William A. Gatehouse, Jr.
Student Member

▶ On May 8, 26 members of the Academy's IAS Student Branch had an interesting time on a visit to Republic Aviation Corporation at Farmingdale, L.I., N.Y.

As soon as each of us had signed the register, the group was given a short talk by Mr. Marrone, who is Engineering Administrator at Republic. Mr. Marrone discussed various aspects of the company and gave certain suggestions to aid any young engineer entering the design field. Mr. Marrone told us that of the 29,000 employees working for the company, 1,700 of them are in the Engineering Department. He also gave us a thumbnail sketch of the different parts of the Engineering Department and touched upon the operation of each one. After answering our questions, Mr. Marrone and Mr. Cherwony, Assistant Project Engineer on the RF-84F, showed us the Engineering Department.

Mr. Marrone then invited us to be his guests for luncheon in the cafeteria. Immediately following the luncheon, Mr. Cherwony showed us a motion picture that dealt with the structural limitations of the F-84G. The film demonstrated the different "g" loads that the F-84G can withstand under different flight conditions.

We were then taken around the assembly line and saw the F-84F in various stages of production—from the raw stock to the finished aircraft. The first thing that we saw was the place where the parts are received. We also saw one of the largest hydraulic presses in the country. Mr. Marrone pointed out to us where Republic is beginning the construction of a new and larger hydraulic press. It was interesting to note that the fuselage of the F-84F is made in two sections. In this way, the engine may

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IAS Student Members from Cal-Aero Technical Institute are shown during the April 2 field trip to the San Diego plants of Solar Aircraft Company and Ryan Aeronautical Company.

be removed and a new one installed in less than 1 man-hour. As we moved along the assembly line, we became increasingly aware of the close tolerances that must be maintained in designing aircraft.

Cal-Aero Technical Institute

Gary N. Wagner
Secretary-Treasurer

The Cal-Aero Technical Institute Student Branch of the IAS took its quarterly field trip to Solar Aircraft Company and Ryan Aeronautical Company in San Diego, Calif., on April 2. The group was greeted by J. M. Sayre, Public Relations Manager of Solar Aircraft, and was then split up into small groups for a tour of the plant. A few of the items of interest seen were the small gas-turbine engine used to drive a pump or generator; the Solaramic process used on many of the hot-section components of jet and conventional piston engines; and expansion bellows used for moving joints. A short talk was given by Tom Cairn, Chief Design Engineer, and Clyde Seymour, Assistant Manager of Manufacturing. They presented a brief history of Solar and explained some of the engineering features found at the company.

After lunch, the group was assembled at Ryan Aeronautical and was received by Curtis L. Bates, Assistant Director of Engineering, and William P. Brotherton, Public Relations Supervisor. Items of interest seen at the Ryan plant were construction of the aft sections for Boeing's KC-97 Tanker; numerous jet-engine hot-section components; and the Ryan Firebee. Ryan has an extensive welding section, of which the company can be well proud. The large spotwelders are truly ingenious machines and are capable of handling entire external fuel tanks or afterburners.

After the tour, we were served coffee and doughnuts, and men from the Engineering Department mingled with the group to answer questions.

▶ The Cal-Aero Student Branch held its monthly dinner meeting on April 14. The guest speaker was D. K. Warner, Group Leader, Engineering Flight Test, North American Aviation, Inc. He gave an excellent talk on the method of conducting world record speed runs at Salton Sea, Calif. Mr. Warner discussed the trials and tribulations encountered in winning speed records.

Of special interest were the problems arising from the establishment of the record set by the F-100 Super Sabre. North American had the record, lost it to the British, who in turn lost it to the Douglas Skyray. The F-100 then set a new record, winning it on a technicality.

Colored slides and films on the F-86 and F-100 were shown.

Indiana Technical College

Harold R. Woodhouse, *Secretary*

At the last meeting of the spring term, held on May 11, Chairman Harold Coffman announced the results of the Opinion Poll and the Student Award.

The Opinion Poll is held each term for the graduating students of the Aeronautical Department. Members of the IAS Student Branch rate the graduating students on the basis of their scholastic standing, character, popularity, enthusiasm, and contribution to the Aeronautical Department. Leroy Dimmick was the winner for the spring term.

This year's winner of the Student Award was Harold Swallow, now employed by Chance Vought Aircraft, Inc. The award is given to the student with the highest scholastic average during the academic year. It consists of a cash award together with the engraving of the winner's name on a bronze plaque hanging in the lobby of the college.

Our Faculty Adviser, Benjamin Dow, expressed his appreciation for the contribution made to the Annual Open House program by the Aeronautical Department.

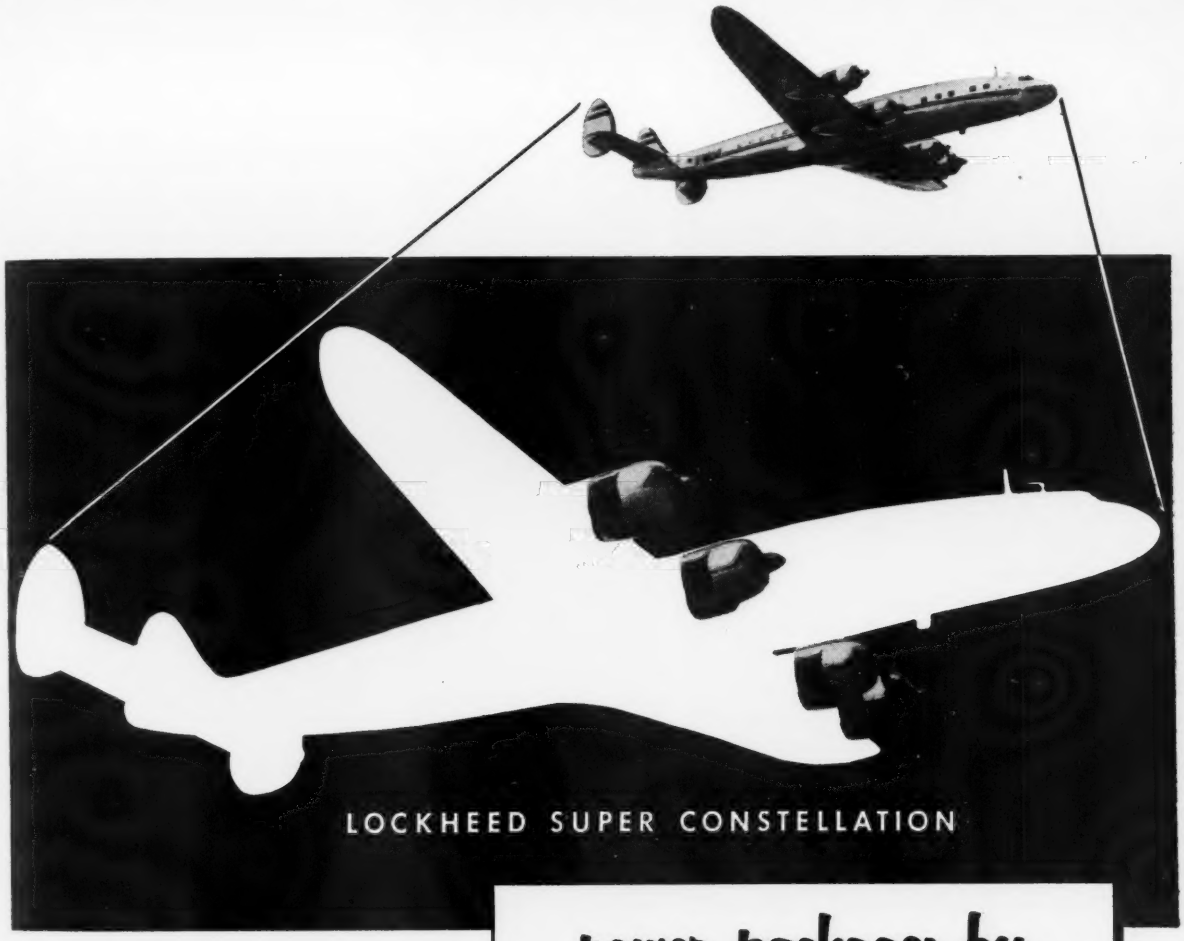
The Pennsylvania State University

Ralph N. Straley, II
Secretary-Treasurer

A regularly scheduled meeting of The Pennsylvania State University Student Branch of the IAS was held on May 20 on the Penn State campus with 30 members attending.

Arrangements were made to hold a picnic at Black Moshannon State Park.

Shown at the April 14 Dinner Meeting of the Cal-Aero Technical Institute IAS Student Branch are *(left to right)*: W. F. Wennhold, Vice-Chairman; E. Lundby, Chairman; D. K. Warner, Guest Speaker from North American Aviation, Inc.; and G. N. Wagner, Secretary-Treasurer.



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The election of officers for the next school year was held. This resulted in the following officers being elected: Chairman, Ralph N. Straley; Vice-Chairman, George Walker; and Secretary-Treasurer, Allen Weber.

Two films from North American Aviation, Inc., were then shown. One of these films depicted the F-86 Sabre as used for training purposes and in the Korean War. The second film showed other North American planes being flown by the Navy and the Air Force. An interesting feature of the films was the precision flying done by the F-86 pilots during training.

Tri-State College

Robert R. Spatz, *Secretary*

The regular Spring Term Banquet was held on May 10 at Twin Gables, Columbia, Ohio. Thirty-two members were present.

The speaker of the evening was Fred Strickland, Chief Design Engineer, Piper Aircraft Corporation, whose subject was the "Development of the Piper Apache." In his talk, Mr. Strickland touched upon design problems, including flow separation between the engine nacelles and fuselage.

The talk was accompanied by slides that demonstrated certain phases of the testing and development of the Apache.

University of Illinois

John Locke, *Secretary*

The University of Illinois Student Branch of the IAS held its annual Spring Banquet on May 19 at the University Men's Club. Thirty-two members were present. The banquet was cosponsored with Sigma Gamma Tau, National Aeronautical Engineering Honorary Fraternity.

The speaker for the evening was Prof. Thomas Page, of the Institute of Government and Public Affairs. He gave a timely talk entitled "Long Range Effects of McCarthy's Methods." A lively discussion period followed.

Upon completion of the talk, Chairman Dwight Moberg called the short business meeting to order. A financial report was given by the Treasurer, Gene Tisserand. Elections were held, and next semester's officers were chosen. They are: Chairman, Phil DeProtine; Vice-Chairman, Jim Kuczma; Treasurer, Dick Sommerville; Secretary, John Locke; and Engineering Council Representatives, Jerome Rachner and Fred Snyder. The Faculty Adviser is Harry H. Hilton.

The meeting was then adjourned.

University of Michigan

Roger J. Nyenhuis, *Secretary*

The meeting of April 14 was called to order by Chairman Bill Sproull. It was announced that Prof. Maurice A. Brull had accepted the invitation to serve as the Branch's Faculty Adviser. He replaces Prof. Julius D. Schetzer who during the past year has donated considerable time and effort to this Branch.

The newly elected officers of this Branch are: William C. Sproull, Chairman; Ralston W. Schultz, Vice-Chairman; Roger J. Nyenhuis, Secretary; and Robert J. Lauer, Treasurer.

After some debate concerning when and where to have the Branch's annual picnic, it was decided that May 15 at Kensington Park would be agreeable to the majority of the members.

Three films from McDonnell Aircraft Corporation were shown at this meeting. These were: *The XHJD-1*, *Little Henry*, and *The Banshee*.

As the main event of the meeting, William Fisher presented a paper on "The Problem of Performance as Applied to Interceptor Type Aircraft." The paper compared the classical and energy methods of getting a plane from the ground to a 40,000-ft. altitude. He stated that the time required using the flight program indicated by the energy method was 1 min. less than that necessitated by the classical method. In concluding his talk, the speaker, indicated the significance of 1 min. in an interception problem.

After the presentation of the paper, criticism was offered by the members to help Mr. Fisher prepare the paper for presentation at the Annual Student Paper Competition sponsored by the IAS Detroit Section. The participating schools in this competition are the University of Detroit, Wayne University, and the University of Michigan.

University of Notre Dame

Martin Kenehan, *Secretary*

The Notre Dame Student Branch of the IAS held its fifth meeting of the spring semester on Thursday evening, May 6. The first business on hand was the election of officers. Those elected are: Chairman, Martin Kenehan; Vice-Chairman, Robert Gervais; Secretary, Leon Ring; and Treasurer, Dave Austgen.

The annual club picnic was scheduled for Sunday, May 23. The future officers were delegated to make plans for the picnic.

After a discussion of the May 14 Engineers' Open House, the meeting was closed and refreshments were served. Thirty members were present.

▶ The final meeting of the spring semester was held by the Notre Dame IAS Student Branch on Wednesday, May 26. The meeting was opened by Chairman Bob Meister, and the minutes of the previous meeting were read and approved.

Awards won during the Engineering Open House week end were announced. The display put on by the Aeronautical Engineers took first place. Our chariot came in second—both in the chariot race and in the contest to determine the best-built chariot.

A picnic, at which hot dogs and pop were served, was held behind the Aeronautical Building. This was highlighted by the annual football game between the graduating seniors and the rest of the undergraduates. This time the seniors came out on top by a score of 18 to 6.

Two movies, one on the Bell X-1 and the other on the 1953 Farnborough Air Show, brought the meeting to an end. Twenty-five members were present at this meeting.

University of Tulsa

Donald S. Boyd
Secretary-Treasurer

The final meeting of the University of Tulsa Student Branch of the IAS for the 1953–1954 school year was called to order at 11:00 a.m. May 13 by the Student Chairman, Jack Owens. The attendance was 17.

Elections were held for the student officers who will take office at the beginning of the fall term. Donald Boyd received the position of Student Chairman, and Don Funk was elected Vice-Chairman. A motion was made and carried to leave the office of Secretary-Treasurer open until the first meeting of the fall term.

A committee was appointed to select a gift for J. C. Klotz, Honorary Chairman, who has been ill. The members voted to take up a collection to supplement recent expenditures from the treasury.

The meeting adjourned at noon.

Members Elected

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the REVIEW.

Elected to Associate Fellow Grade

Holder, Douglas William, Ph.D., Sr. Principal Scientific Officer, Natl. Physical Lab. (England).

O'Brien, M. P., B.S.Engrg., Dean, College of Engrg., Univ. of California.

Seddon, John, Ph.D., Principal Scientific Officer, Ministry of Supply.

Transferred to Associate Fellow Grade

Arnold, Alison M., B.S.M.E., Sr. Aeronamicist, Stanley Aviation Corp.

D'Anna, Peter W., B.S. in Ae.E., Proj. Engr., Prelim. Design, Stanley Aviation Corp.

Harned, Malcolm S., M.S. in Ae.E., Chief Tech. Engr., Marquardt Aircraft Corp.

Hilton, Harry H., Ph.D. in Theoretical & Applied Mechanics, Asst. Prof., Dept. of Aero. Engrg., Univ. of Illinois.

Hurkamp, Charles Hartner, B.S. in M.E., Helicopter Chief Engr., McDonnell Aircraft Corp.

Katzoff, Samuel, Ph.D. in Chemistry, Asst. Chief, Full-Scale Research Div., Langley Aero. Lab.; Head, Large-Scale Research Br.; Chairman, Langley Committee on Gen. Aerodynamics, Langley Aero. Lab., NACA.

Rassieur, W. T., M.S.Ae.E., Rear Adm., USN (Ret.); Military Requirements Rep., Lockheed Aircraft Corp. (Burbank).

Robischon, E. W., Western Region Mgr., IAS.

Schultz, Arthur D., B.S.E.Aero., Sr. Mech. Engr., Argonne Natl. Lab.

Elected to MEMBER Grade

Bonnett, Edward W., B.S.M.E., Product Engr., The General Tire & Rubber Co.

Christopher, Kenneth W., B. of Ae.E., Aero. Research Scientist, NACA, Langley AFB.

Dowden, Percy R., Chief, Prelim. Engrg. Design Section, Canadair, Ltd.

Engel, Rolf, Chief Engr. & Tech. Dir., CERVA (Egypt).

Evans, Albert J., B.S.M.E. (Aero.), Aero. Research Scientist–Staff Member; Secy. of NACA Subcommittee on High Speed Aerodynamics; Secy. of NACA Subcommittee on Internal Flow; NACA (Washington, D.C.).

Eyestone, S. Frederick, B.S.E.E., Chief, Autocontrol Section, Electromechanical Engrg. Dept., North American Aviation, Inc.

Felgar, Robert P., Jr., Ph.D., Sr. Aerophysics Engr., Convair (Ft. Worth).

Glassman, Irvin, Dr. of Engrg., Research Assoc., Aero. Engrg. Dept., Princeton Univ.

Gross, Robert A., Ph.D., Research Engr., Fairchild Engine &-Airplane Corp.

Howard, Vincent W., M.E., Staff Engr., Flight Control Lab., Mass. Inst. of Technology.

Howes, Walton, B.S. in Optics, Aero. Research Scientist, Lewis Flight Propulsion Lab., NACA.

Mahlmann, Charles V., M.S., Cons. Engr., Self-employed.

Margrave, W., B.S.M.E., Div. Engr., The Parker Appliance Co.

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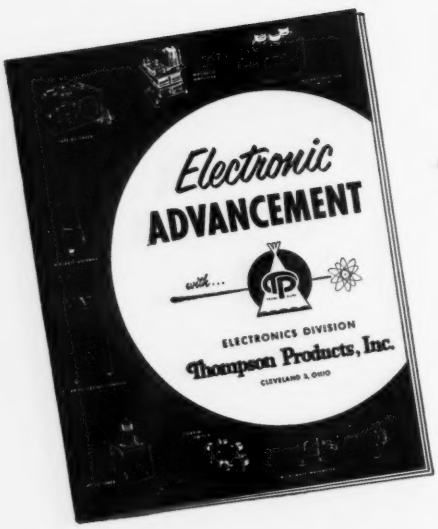

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Miller, Matha M., B.A. in Physics, Acoustics Engr., Douglas Aircraft Co., Inc. (Santa Monica).

Moses, Jason J., B.S.E.E., Aerodynamics Engr. "A," Ryan Aeronautical Co.

Musselman, Edward C., Capt. & Check Pilot, Western Air Lines (Los Angeles).

Oppenheimer, Frank L., M.S. in M.E., Controls Devel. Engr., Thompson Products, Inc.

Pfankuch, Leo A., B.Sc., Gen. Mgr. & Chief Engr., Sturgess, Inc.

Preston, Frederick W., B.S.M.E., Supvr., Install. & Service Mechanical, General Electric Co. (Los Angeles).

Ross, David T., Design Engr. "A," Prelim. Design Div., Lockheed Aircraft Corp.

Rossbach, Richard J., M.S.M.E., Secy., Subcommittee on Compressors & Turbines, NACA (Washington, D.C.).

Rutledge, John E., Chief Inspector, McDonnell Aircraft Corp.

Sabbia, J. R., Asst. Proj. Engr., Chance Vought Aircraft, Inc.

Schmitt, Heinz E., Dr. of Engrg., Proj. Engr., Wright Aero. Div., Curtiss-Wright Corp.

Smith, Henry J., M.E.E., Supvr., Electronics Operations & Lab. Group, Chance Vought Aircraft, Inc.

Stencil, Fred B., Dipl. Ing., Chief, Special Projects & Chief, Swiss Guided Missiles Delegation, assigned to Alamagordo, N.M., Oerlikon Tool & Arms Corp. of America.

Utgoff, Vadym V., M.S. in Ae.E., Comdr., USN; Planning Officer, Air Br., Office of Naval Research (Washington, D.C.).

Wentworth, Carl B., M.S., Aero. Research Scientist, Lewis Flight Propulsion Lab., NACA.

Wildhorn, Soreel, M. of Ae.E., Aerodynamicist "A," Lockheed Aircraft Corp.

Wilson, George T., Group Engr., Wing & Nac Struct., Douglas Aircraft Co., Inc.

Wimbrow, William R., M.E.Sc., Proj. Engr., Propulsion Wind Tunnel Facility, ARO, Inc.

Wolff, William J., B.S.Ae.E., Aerodynamics "A," Lockheed Aircraft Corp.

Transferred to MEMBER Grade

Bidwell, Jerold M., M. of Ae.E., Supvr., Aerodynamics Devel. Testing Unit, The Glenn L. Martin Co.

Cartaino, T. F., B.S.Ae.E., Proj. Engr., Allison Div., General Motors Corp.

Clark, Denver Dudley, B. of Ae.E. & B. of I.E., Aircraft Sales Engr., McDonnell Aircraft Corp.

Crabtree, Lewis F., Ph.D.Ae.E., Sr. Scientific Officer, Ministry of Supply, Royal Aircraft Establishment.

Davis, Robert A., M. of Ae.E., Sr. Engr. & Group Leader, Sperry Gyroscope Co. Div., The Sperry Corp.

Freeman, Carroll, B.S.Ae.E., Power Plant Design Group Leader, Goodyear Aircraft Corp.

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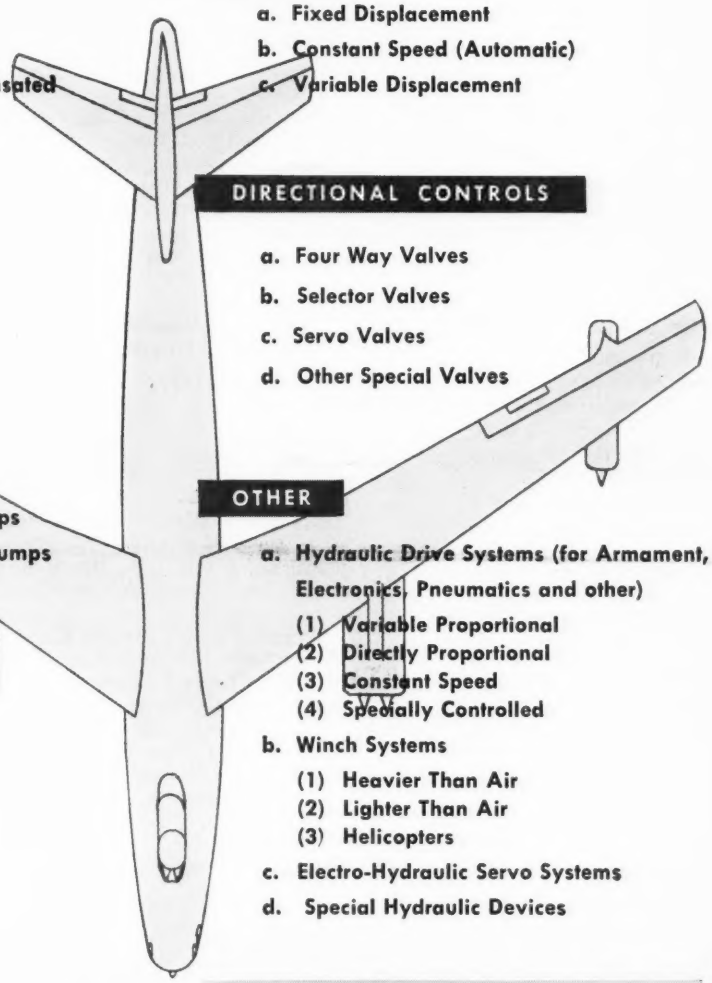

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Lynch, Ernest John, Test Engrg. Supvr., A. V. Roe Canada, Ltd.

Nankey, Ralph Wallace, M.S.M.E., Dynamics Engr., Bell Aircraft Corp.

Terry, William B., Jr., B.S.Ae.E., Test Facilities Engr., Flight Refueling, Inc.

Ting, Lu, Sc.D. in Ae.E., Special Design Engr., Foster Wheeler Corp.

Todd, Miles Johnston, A.E., Struct. Proj. Test Engr., Chance Vought Aircraft, Inc. (Dallas).

Yardley, John Finley, M.S. in Applied Mechanics, Proj. Stress Engr., McDonnell Aircraft Corp.

Elected to Associate Member Grade

Byard, William K., Flight Engr., Trans World Airlines.

Obertino, James R., Asst. Supt. of Flight Engineers, Trans World Airlines.

Woodward, William C., A.B., Mgr., Forging Sales, Aluminum Co. of America.

Elected to Technical Member Grade

Berch, Julian P., B.M.E., Hydraulic Engr., Republic Aviation Corp.

Bisceglia, Angelo M., Jr. Engr., Northrop Aircraft, Inc.

Burns, Gene C., M.S., Flutter Analyst, McDonnell Aircraft Corp.

Byers, Richard A., B.Sc.M.E., Design Engr., Lockheed Aircraft Corp. (Burbank).

Chalk, Joseph B., B.S.Ae., Design Engr., Convair (San Diego).

Esten, Harold, B.M.E., Engr., Engineering & Research Corp.

Falanga, Ralph A., B.Sc., Research Scientist, NACA, Langley AFB.

Fink, Wally B., B.S. in M.E., Head of Research, Zenith Plastics Co.

Fioretti, Adrian P., B.M.E., Tech. Engr., Marketing, AGTD, General Electric Co. (Evendale).

Gaefcke, Roger L., B.Sc.M.E., Jr. Engr.—Flight Test, Lockheed Aircraft Corp. (Burbank).

Gleason, Richard E., B.S. in M.E., Struct. Engr., North American Aviation, Inc. (Downey).

Havill, C. Dewey, B.S.—Physics, Aero. Research Scientist, Ames Aero. Lab., NACA.

Holway, Harold P., Engrg. Asst., Jet Propulsion Lab., California Inst. of Technology.

Knittle, Walter A., B.E.M.E., Research Engr., Propulsion Section, North American Aviation, Inc.

Lesser, Henry E., B.S. in C.E., Jr. Engr., Chance Vought Aircraft, Inc. (Boston).

McDowell, E. C., B.S.Ae.E., Field Engr., Chance Vought Aircraft, Inc.

Miller, Carroll I., Operations Engr., R. & D., Alloy Engrg. & Casting Co. (Champaign, Ill.).

Mills, George S., B.S.Ae.E., Test Pilot, McDonnell Aircraft Corp.

Schellert, Jerry L., B.S.Ae.E. (Power Plant), Jr. Engr.—Aerodynamics, North American Aviation, Inc. (Downey).

Woodwell, Thornton G., B.S.M.E., Design Asst., Pratt & Whitney Aircraft Div., United Aircraft Corp.

Transferred to Technical Member Grade

Bailey, Robert S., B. of Ae.E., Flight Test Analysis Jr. Engr., Chance Vought Aircraft, Inc.

Balgeman, Earle, Assoc. Engr., Missile Systems Div., Aerodynamics Dept., Lockheed Aircraft Corp. (Van Nuys).

Bodnarchuk, Frederick R., Assoc. Engr., The Glenn L. Martin Co.

Boucher, Roland J. S., B.S. in Ae.E., Stress Engr.—Training, A. V. Roe Canada, Ltd.

Brunelle, Eugene J., Jr., B.S.E. (Aero)., Grad. Student, Univ. of Michigan.

Calandra, Joseph A., Engrg. Draftsman, Republic Aviation Corp.

Clark, Robert H., B.S. (Aero.), 2nd Lt., USAF; Student Officer, 3303 Pilot Training Sq., Bartow Air Base (Florida).

Cubbison, Robert W., B.S.M.E., Aero. Research Intern, NACA (Cleveland).

Ditzler, Worden L., B.S. (Air Transportation), Passenger Agent, United Air Lines.

Hanson, Wayne Q., B. S., Field Service Engr., Westinghouse Electric Corp.

Henry, Robert E., B.S., Design Engr., Controls Section, Chance Vought Aircraft, Inc.

Houston, Carl L., M.S., Capt., USAF; Admin. Contracting Officer, WADC Procurement, Wright-Patterson AFB.

Howell, John W., B.S. in Ae.E., Jr. Engr. "B," Struct. Dynamics Unit, Boeing Airplane Co. (Seattle).

Joyce, Joseph P., B. of Ae.E., 2nd Lt., USAF; Student, USAF Inst. of Tech., Wright-Patterson AFB.

Kozlowski, Carroll J., Jr. Struct. Engr., Sikorsky Aircraft.

Linder, Douglas W., B.S., Engrg. Asst.—Aerodynamics, Northrop Aircraft.

Luessen, Gordon, B.S. in Ae.E., Engr., Univ. of Wichita Engrg. Research.

McGregor, Howard N., B.S. in Ae.E., Research Engr., Ford Motor Co.

Newton, Earl W., M.S. in Ae.E., 1st. Lt., USAF; Aero. Engr., Icing Unit, All Weather Test Br., WADC, Wright-Patterson AFB.

Perlman, Edwin F., B.S. in Ae.E., Jr. Engr., Struct. Design Group, Douglas Aircraft Co., Inc. (Santa Monica).

Peterson, John G., Jr. Design Engr., American Helicopter Div., Fairchild Engine & Airplane Corp.

Rubenstein, Murray, Engrg. Draftsman "B," Republic Aviation Corp.

Sardella, Gerald, B.S. in Ae.E., Assoc. Engr., Dynamics Test Section, Struct. Dept., The Glenn L. Martin Co.

Schafer, Everett M., Jr. Aerodynamic Engr., Ryan Aeronautical Co.

Senchuk, Peter G., Liaison Engr., Douglas Aircraft Co., Inc. (El Segundo).

Small, Richard K., Jr. Engr.-Draftsman "A," Northrop Aircraft, Inc.

Stein, Arnold M., Aerodynamicist, Curtiss-Wright Corp. (Carlstadt).

Swallow, Harold, B.S. in Ae.E., Aerodynamicist, Chance Vought Aircraft, Inc.

Tepper, Donald S., Sr. Detailer, Chance Vought Aircraft, Inc.

Whitehurst, Rex A., B.S., 2nd Lt., USAF; Aerodynamic Devel. Engr. WADC, Wright-Patterson AFB.

Withers, Clifton C., B. S., Aerodynamicist, Chance Vought Aircraft, Inc.

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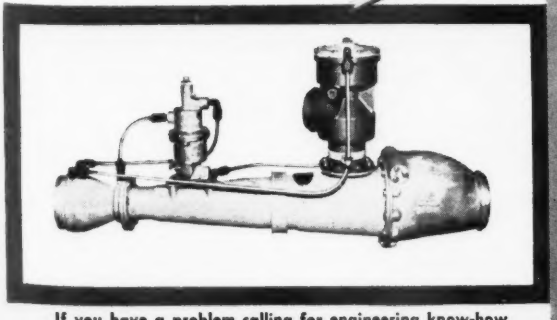

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St. Louis Section's First Annual Student Paper Competition

(*Continued from page 27*)

Meeting at the Forest Park Hotel in St. Louis, attended by about 75 people. After cocktails (compliments of McDonnell Aircraft Corporation) and dinner, Mr. Meyer opened the meeting. The winners of the competition were formally introduced to the Section membership and were presented with their awards and scrolls of achievement.

The principal speaker at the meeting was Comdr. Charles A. Van Dusen, of the Staff of the Chief of Naval Operations, whose subject was "Naval Air Operations." Commander Van Dusen entered the Navy in 1937 and completed flight training at Pensacola. He served in the South Pacific during World War II and became Photography Officer for the Pacific while on the staff of ComAirPac. From 1949 to 1951, Commander Van Dusen was Deputy Director of the Photographic Division of the Bureau of Aeronautics. He also served in Europe as Assistant Air Planning Officer for the Joint American Military Advisory Group in London. He has just returned from a tour of duty with General Gruenther's U.S. Joint Staff in Germany.

Commander Van Dusen's interesting talk enlightened the audience on the role of the aircraft carrier and the newest naval air weapons in our country's efforts to keep the sea lanes and strategic coastal waters from falling into the hands of an aggressor nation.

Of primary interest and importance were the great advancements being made in aircraft-carrier design. The Commander, with the aid of excellent films, indicated some of the major changes we can expect in carrier operations. The handling of jet aircraft on carriers is in many instances much more complex and exacting than that of propeller-driven airplanes. Special care must be taken by the deck crews in order to ensure the maximum safety for the carrier personnel, as well as for the flight crews. The deck crews must be thoroughly trained in the art (as it certainly is) of securing, taxiing, relocating, landing, and catapulting jet aircraft. Stronger, more effective, and more reliable arresting gear and crash barriers have been installed to provide for the landing of the faster jets. A more rigid and coordinated landing procedure is also necessary, since, at the conclusion of a mission, jet fighters have very little fuel remaining, and, in the words of Commander Van Dusen, "At low altitudes, a jet engine consumes fuel faster than you can pour water from one bucket into another."

One of the most important contributions made to increase the effectiveness of an aircraft carrier was the introduction of the canted deck. A film was shown illustrating its great advantages in operations as well as in safety.

Commander Van Dusen also gave the audience interesting information on the Navy's new Vertical-Take-Off turboprop airplane, the XFY-1. A film showing many of the features of the aircraft and its first taxi tests was a special treat for the audience.

The Commander ended the program on a humorous note by showing a training film, cartoon style, of a Dr. Jekyl-and-Mr. Hyde-type fighter pilot whose perverted idea of relaxation—which was a menace to every cow, bush, barn, and convertible driver in the area—led to his inevitable expulsion from the Service.

A. H. MADRICK
Publicity Chairman
St. Louis Section

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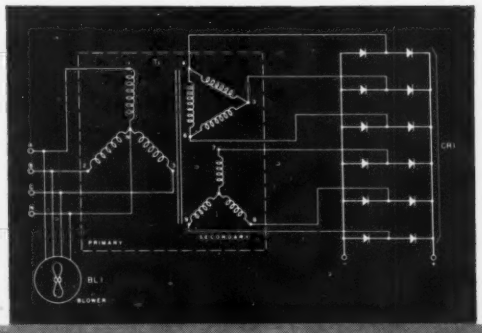

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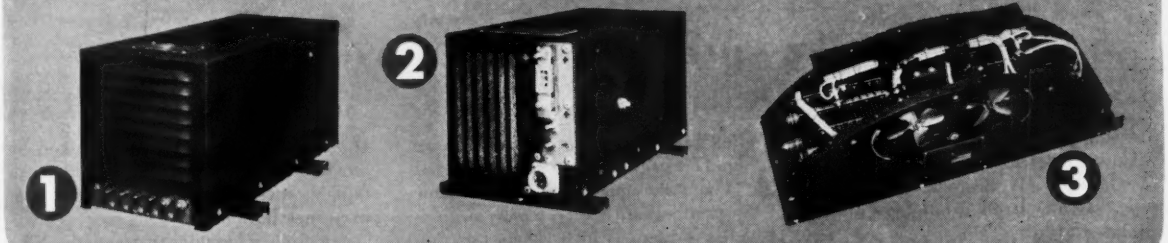

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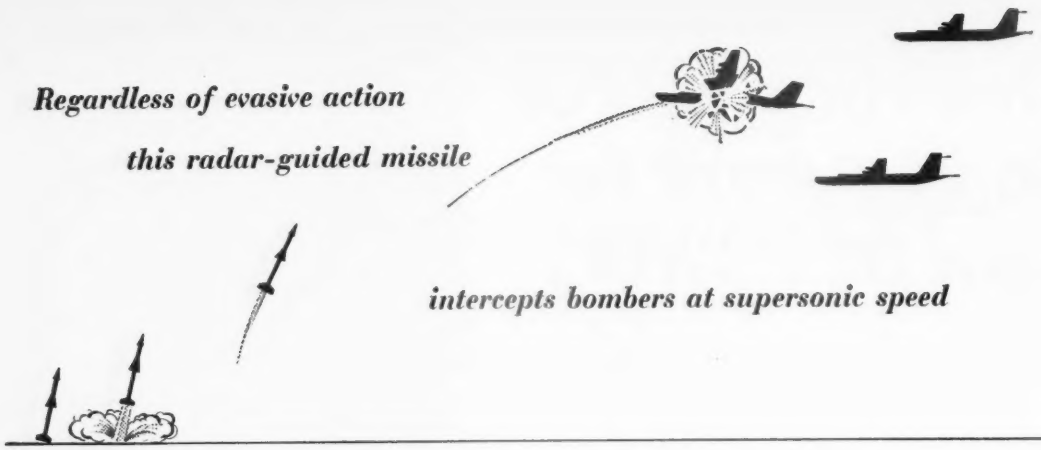


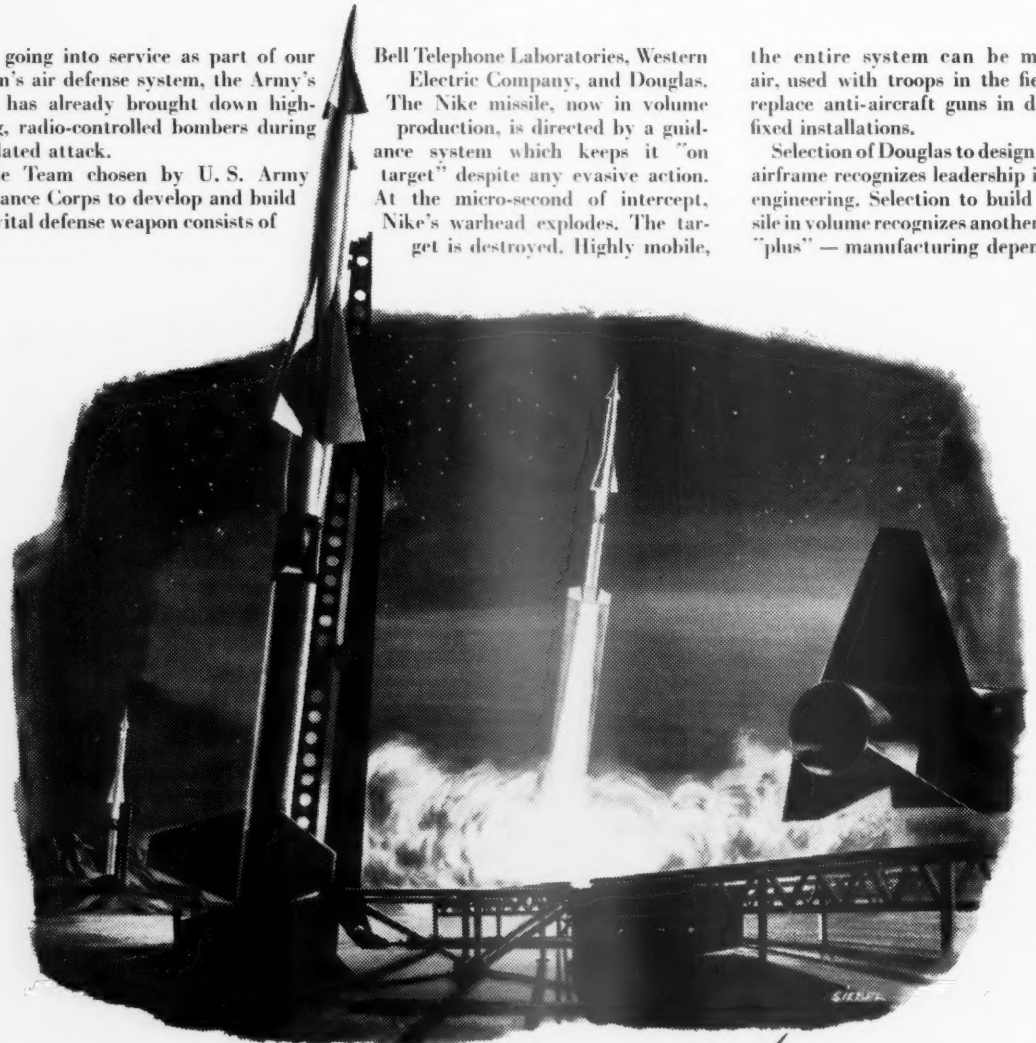
intercepts bombers at supersonic speed

Nike—product of teamwork

Now going into service as part of our nation's air defense system, the Army's *Nike* has already brought down high-flying, radio-controlled bombers during simulated attack.

The Team chosen by U. S. Army Ordnance Corps to develop and build this vital defense weapon consists of Bell Telephone Laboratories, Western Electric Company, and Douglas. The Nike missile, now in volume production, is directed by a guidance system which keeps it "on target" despite any evasive action. At the micro-second of intercept, Nike's warhead explodes. The target is destroyed. Highly mobile, the entire system can be moved by air, used with troops in the field, or to replace anti-aircraft guns in defense of fixed installations.

Selection of Douglas to design the Nike airframe recognizes leadership in missile engineering. Selection to build the missile in volume recognizes another Douglas "plus" — manufacturing dependability.



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A Guide to the Current Literature of Aeronautical Research and Engineering

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Aerodynamics

Boundary Layer & Thermoaerodynamics

Adaptation des Trompes á Induction Assurant l'Aspiration et le Soufflage Combinés sur une Aile d'Avion. J. P. Chevallier and P. Jousserandot. *La Recherche Aéronautique*, Sept.-Oct., 1953, p. 25. In French. Adaptation of combined aspirant suction and blower devices to control the boundary layer on an airfoil.

The Effect of Leading-Edge Bluntness on a Laminar Supersonic Boundary Layer. W. S. Bradfield, D. C. DeCoursin, and C. B. Blumer. *J. Aero. Sci.*, June, 1954, p. 373. USAF-sponsored experimental investigation at U. of Minn. to study the relationship of the presence of a detached shock wave at the plate leading edge and the observed discrepancy between the momentum loss predicted by the idealized theory and the measured momentum losses.

The Effect of Mass Transfer on the Compressible Turbulent Boundary-Layer Skin Friction and Heat Transfer. William H. Dorrance and Frank J. Dore. *J. Aero. Sci.*, June, 1954, p. 404. 10 refs. Derivation of formulas for the case of mass injected into or withdrawn from the boundary layer normal to the solid surface.

Effect of Single Roughness Elements on the Heat Transfer From a 1:3 Elliptical Cylinder. R. A. Seban, S. Levy, D. L. Doughty, and R. M. Drake, Jr. *Trans. ASME*, May, 1954, p. 519. USAF Flight Research Lab.-sponsored investigation of the possibility of producing turbulent boundary layers on the cylinder under certain conditions.

Nouvelles Mesures dans la Couche Limite d'une Plaque Plane, des Intensités de Turbulence, et des Corrélations dans le Temps; Spectres. A. Favre, J. Gaviglio, and R. Dumas. *La Recherche Aéronautique*, Mar.-Apr., 1954, p. 7. 13 refs. In French. Experimental measurements of the intensity of turbulence and correlation of space and time and the energy spectrum in the boundary layer of a plane surface.

Sur une Méthode Approchée de Calcul de la Couche-Limite Laminaire Compressible pour Gradient de Pression Extérieure, Loi de Température à la Paroi et Nombre de Prandtl Quelconques. E. A. Eichelbrenner. *La Recherche Aéronautique*, July-Aug., 1953, p. 3. 14 refs. In French. An approximate method to calculate the compressible laminar boundary layer for external pressure gradients at various surface temperatures and at any Prandtl Number.

The Transverse Curvature Effect in Compressible Axially-Symmetric Laminar Boundary Layer Flow. Ronald F. Probstein and David Elliott. *Princeton U. Dept. Aero. Eng. Rep. 261*, Apr., 1954. 63 pp. 32 refs.

Control Surfaces

Determination of Reversal Speed of a Wing with a Partial-Span Flap and Inset Aileron. W. G. Molyneux and E. G. Broadbent. *Gt. Brit., ARC R&M 2793* (Feb., 1950), 1954. 10 pp. BIS, New York. $0.75.

Influence of Airfoil Trailing-Edge Angle and Trailing-Edge-Thickness Variation on the Effectiveness of a Plain Flap at High Subsonic Mach Numbers. Albert D. Hemenover and Donald J. Graham. *U.S., NACA TN 3174*, June, 1954. 101 pp.

Some Aerodynamic Characteristics of Wide-Delta Cruciform Wings with Canard-Delta or Trailing-Edge Control Surfaces. Kelsey Walker, Jr. *Douglas Rep. SM-14976*, Nov., 1953. 58 pp. Use of the linearized supersonic wing theory to investigate forces and moments about the cruciform configuration for the case of control surfaces deflected as ailerons and other cases of control deflections as well as to certain other plan forms.

Fluid Mechanics & Aerodynamic Theory

Les Corrélations d'Espace et de Temps dans un Fluide Turbulent. J. Bass. *La Recherche Aéronautique*, Mar.-Apr., 1954, p. 13. In French. Theoretical and experimental investigation of the space-time relations in an incompressible turbulent fluid.

Fluid Dynamics. A. K. Oppenheim and Thomas Baron. *Ind. & Eng. Chem.*, May, 1954, p. 922. 133 refs. Review of the literature.

Molecular Transport Properties of Fluids. E. F. Johnson. *Ind. & Eng. Chem.*, May, 1954, p. 889. 81 refs. Review of the literature.

O Pewnym Zagadnieniu Dwuwymiarowych Przepływów Turbulentnych (On a Certain Problem of the Two-Dimensional Turbulent Flow). Jerzy Litwiniszyn. *Arch. Mech. Stosowanej* (Warsaw), No. 2, 1953, p. 273. 14 refs. In Polish; abridged in English. Analysis of problems in terms of the phenomenon of heat conduction in a two-dimensional flowing medium under varying velocity conditions.

O Siłach Występujących w Bezcyrkulacyjnym Ruchu Płaskim Cieczy Doskonałej Dookoła Profilu o Kształcie Zmiennym (Teoria Wiosłującego Ruchu Doskonałego). Michał Lunc. *Arch. Mech. Stosowanej* (Warsaw), No. 2, 1953, p. 167. In Polish; abridged in Russian. Theoretical study of the forces operating about variable round profiles in a time-dependent, steady, noncirculatory, ideal flow.

O Zagadnieniu Fouriera w Warstwie Nieograniczonej (Sur le Problème de Fourier dans une Région Indéfinie). Mirosław Krzyżański. *Arch. Mech. Stosowanej* (Warsaw), No. 4, 1953, p. 584. In Polish; abridged in French and Russian. On a hydrodynamic problem in an indefinite region studied by Litwiniszyn by means of a Fourier parabolic equation.

Quelques Résultats Expérimentaux en Transsonique. Henry Girerd. *La Recherche Aéronautique*, Sept.-Oct., 1953, p. 13. In French. Survey of ONERA and other experimentation on transonic flow-fields at various Mach Numbers with diagrams and charts.

A Study of Hypersonic Small-Disturbance Theory. Milton D. Van Dyke. *U.S., NACA TN 3173*, May, 1954. 51 pp. 37 refs.

Teoria Napedu Odrzutowowodnego Dwuczynnikowego (La Théorie de la Propulsion Hydraulique à Réaction à Deux Fluides). M. Lunc and A. Szaniawski. *Arch. Mech. Stosowanej* (Warsaw), No. 4, 1953, p. 499. In Polish; abridged in French. Theoretical study of hydraulic propulsion of two compressible flows with heat; calculation with diagrams, to solve the thermal and flow problems.

The Use of Tensor Notation to Develop Characteristic Equations of Supersonic Flow. C. N. H. Lock and R. C. Tomlinson. *Gt. Brit., ARC R&M 2632* (Mar., 1949), 1954. 18 pp. BIS, New York. $1.25.

An Approximate Calculation of the Flow of a Viscous Fluid Past a Body Having a Flat End. Jun-ichi Okabe. *Kyushu U., Japan, Rep. Res. Inst. Appl. Mech.*, Apr., 1954, p. 45.

The Flow Past Elliptic-nosed Cylinders and Bodies of Revolution in Supersonic Air Streams. D. W. Holder and A. Chinneck. *Aero. Quart.*, Feb., 1954, p. 317. 16 refs.

Minimum-Drag Ducted and Pointed Bodies of Revolution Based on Linearized Supersonic Theory. Hermon M. Parker. *U.S., NACA TN 3189*, May, 1954. 30 pp. 14 refs. Analytical treatment of problems in terms of a double-integral form related to the source-distribution function for the case of supersonic flow past cones and semi-infinite cylinders.

On the Slow Motion of Viscous Liquid Past a Circular Cylinder. Hikoji Yamada. *Kyushu U., Japan, Rep. Res. Inst. Appl. Mech.*, Apr., 1954, p. 11. Determination of the Reynolds Number at which the rear twin-vortices make their appearance to obtain the solution of the two-dimensional flow field problem by means of the integration of Oseen's linearized equations.

Velocity Distribution on Thin Bodies of Revolution at Zero Incidence in Incompressible Flow. S. Neumark. *Gt. Brit., ARC R&M 2814* (July, 1950), 1954. 42 pp. 15 refs. BIS, New York. $2.85. Development of a new, rapid method analogous to the two-dimensional linear perturbation method and applied to the study of axial flow about twelve different slender bodies at critical Mach Numbers.

Diverses Remarques à Propos du "Gong Sonique." Maurice Roy. *La Recherche Aéronautique*, Nov.-Dec., 1953, p. 3. In French. Remarks on the nature of the "sonic bang" phenomenon in terms of shock-wave behavior.

Étude des Champs Aérodynamiques au Moyen d'une Méthode de Perturbations. F. Lanièce and R. Tisseau. *La Recherche Aéronautique*, July-Aug., 1953, p. 11. In French. Experimental investigation of aerodynamic fields by means of a perturbation method to study shock waves under different conditions.

Étude du Départ d'un Obstacle dans un Fluide au Repos (Écoulements Plans—Écoulement de Revolution). H. Cabannes. *La Recherche Aéronautique*, Nov.-Dec., 1953, p. 8. In French. Analysis of the formation and behavior of shock waves as a consequence of putting into sudden motion an obstacle in a fluid at rest, under the conditions of rectilinear, plane, and stationary flows and flows of revolution.

Multiple Shock Reflection in Corners. Joseph B. Keller. *J. Appl. Phys.*, May,

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1954, p. 588. Use of the theory of regular reflection to yield an explicit algebraic solution of the problem of a finite shock entering a corner from the concave side but without causing diffraction at the edge.

On the Flow Behind an Axially Symmetrical Attached Curved Shock. S. I. Pai. *J. Franklin Inst.*, May, 1954, p. 383. Solutions for the cases of three flow-pattern problems obtained for arbitrary shape of the body of revolution in an isentropic, irrotational, steady, inviscid, and adiabatic supersonic stream.

The Peak Pressure Rise Across an Oblique Shock Emerging from a Turbulent Boundary Layer Over a Plane Surface. Luigi Crucco and Ronald F. Probstein. *Princeton U. Dept. Aero. Eng. Rep. 254*, Mar., 1954. 35 pp. 13 refs. Analytical method using the generalized parameters of Crocco-Lees Mixing Theory.

The State Equation of Water at High Pressures from X-Ray Flash Photographs of High Intensity Shock Waves. R. Schall. (*ZAMP*, No. 6, 1950, p. 252.) *Gt. Brit., MOS TIB Rep. T4204*, Mar., 1954. 6 pp. Translation.

The Transition Through a Contact Region. J. G. Hall. *U. Toronto Inst. Aerophys. Rep. 26*, Jan., 1954. 61 pp. 12 refs. An experimental approximate analysis of the temperature and density transition through the one-dimensional contact region of shock-tube flows.

Internal Flow

Adiabatic One-Dimensional Flow of a Perfect Gas Through a Rotating Tube of Uniform Cross Section. K. Kestin and S. K. Zaremba. *Aero. Quart.*, Feb., 1954, p. 373. 18 refs. Applications to certain helicopter propulsion systems and to wind-driven gas turbines.

Analysis of Turbulent Heat Transfer, Mass Transfer, and Friction in Smooth Tubes at High Prandtl and Schmidt Numbers. Robert G. Deissler. *U.S., NACA TN 3145*, May, 1954. 53 pp. 28 refs. Investigation of internal-flow-with-heat problems at Prandtl and Schmidt Numbers between 0.5 and 3,000.

Convective Heat Transfer for Mixed, Free, and Forced Flow Through Tubes. E. R. G. Eckert and A. J. Diaguila. *Trans. ASME*, May, 1954, p. 497. 11 refs. Generalizations and extensions of results of NACA and other experiments under conditions of turbulent flow in a vertical tube with a length-to-diameter ratio of five.

The Dispersion of Matter in Turbulent Flow Through a Pipe. Geoffrey Taylor. *Proc. Royal Soc. (London), Ser. A*, May 20, 1954, p. 446. 10 refs.

Dynamika Aerosoli (La Dynamique des Aérosols). H. Jarzyna and M. Lunc. *Arch. Mech. Stosowanej* (Warsaw), No. 3, 1953, p. 311. In Polish; abridged in French and Russian. Extension of the equations of the dynamic flows of gases to analyze the movement of the "ideal" aerosol.

Factors Influencing the Optimum Aerodynamic Design of Cooled Turbines. G. F. C. Rogers. *Gt. Brit., ARC CP 155* (July, 1952), 1954. 27 pp. BIS, New York. $0.65.

Nieliniowe Zjawisko Pewnego Przepływu Cieczy Jako Model Reologiczny (Sur un Phénomène Non-Linéaire d'Écoulement d'un Liquide comme un Modèle Rhéologique). W. Olszak and J. Litwiniszyn. *Arch. Mech. Stosowanej* (Warsaw), No. 4, 1953, p. 557. 30 refs. In Polish; abridged in French and Russian. Experimental study, using a rheological model, of the phenomena of nonlinear internal flow problems for the case of flow from an orifice of constant cross section into a tube of variable sections.

Note on the Flow of Liquids in Tubes E. Rune Lindgren. *Appl. Sci. Res., Sect. A*, No. 4, 1954, p. 313. Experimental study of the concept of the laminar sublayer as a special part of the turbulent boundary layer, applied to problems of the transition between laminar and turbulent fluid motion in smooth pipes.

The Performance of the 108 Compressor Fitted with Low Stagger Free Vortex Blading. D. V. Foster. *Gt. Brit., ARC CP 144* (June, 1952), 1954. 36 pp. 16 refs. BIS, New York. $0.90. Development and characteristics of a three-stage design to study three-dimensional flow problems.

Report on the Flow Phenomena at Supersonic Speed in the Neighbourhood of the Entry of a Propulsive Duct. G. H. Lean. *Gt. Brit., ARC R&M 2827* (Mar., 1945), 1954. 15 pp. BIS, New York. $1.15.

Some **Phenomena Associated with Supersonic Liquid Jets.** Brian Dunne

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and Benedict Cassen. *J. Appl. Phys.*, May, 1954, p. 569. Experimental study of high jet velocities to analyze a rotationally-symmetric-wave breakup, which is different from the classical Rayleigh surface tension breakup and the sinuous aerodynamic breakup.

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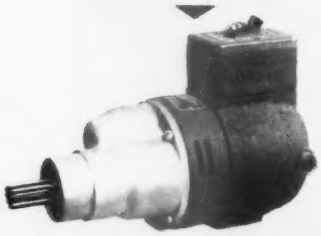

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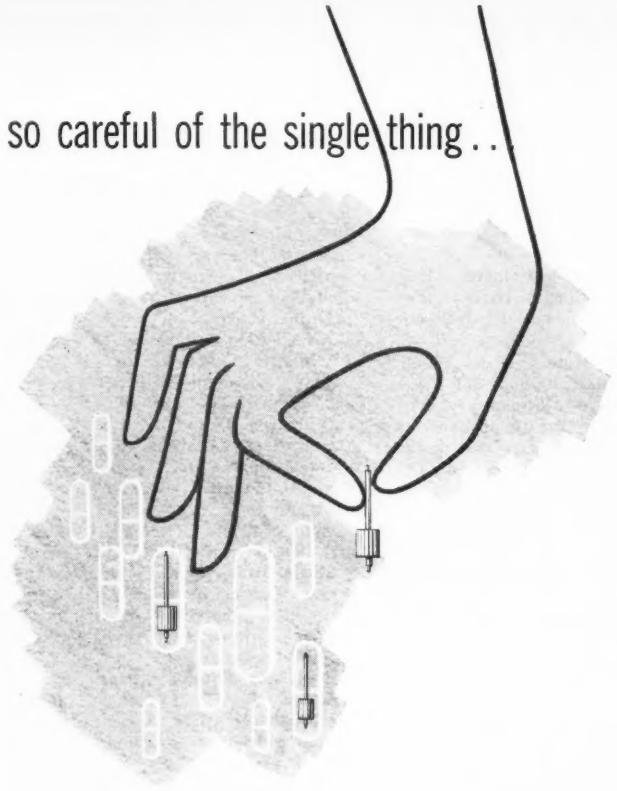

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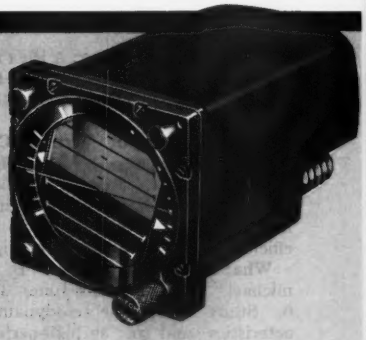

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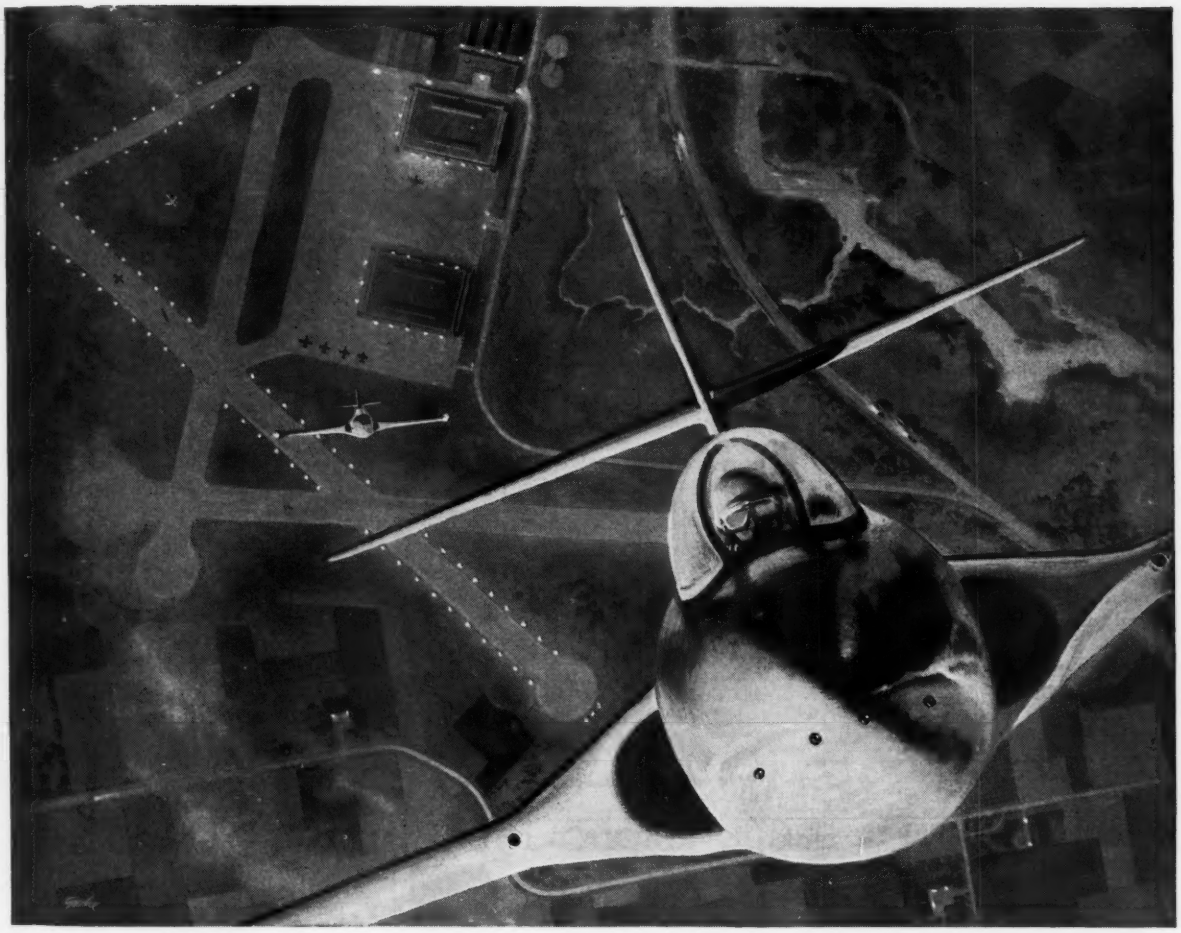

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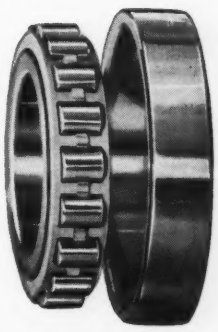

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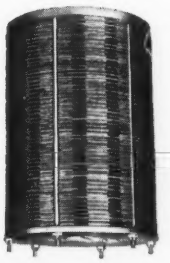

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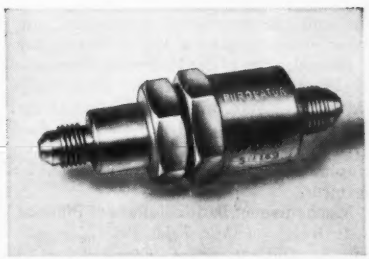

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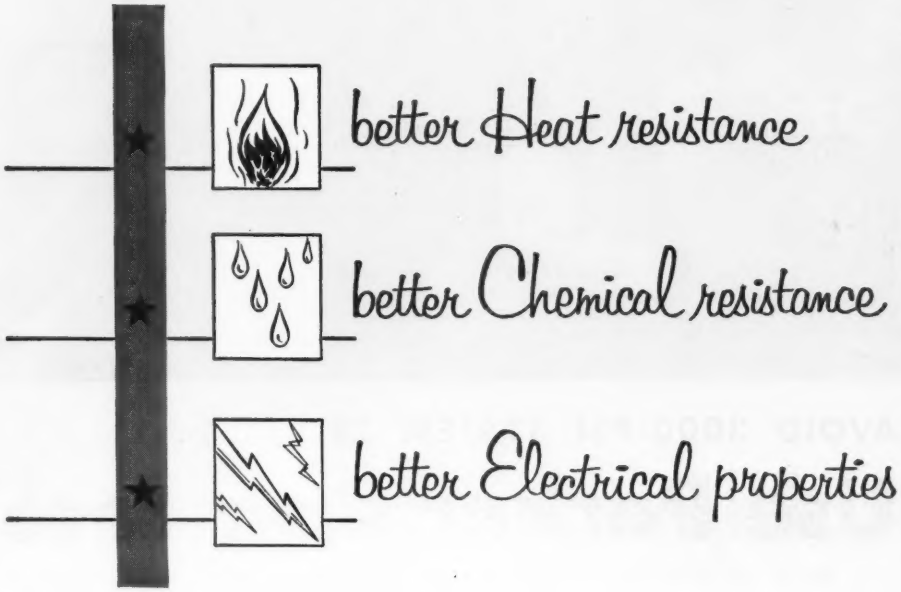

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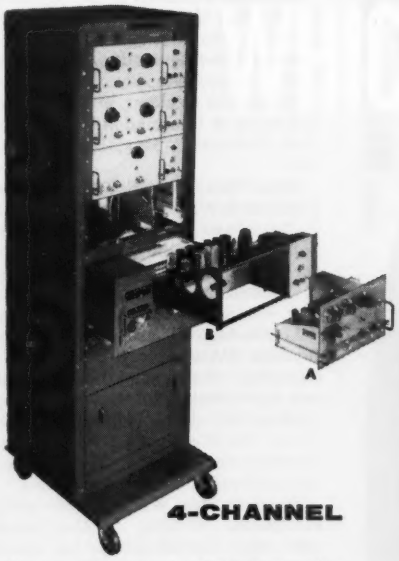

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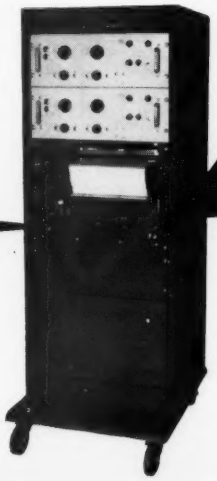

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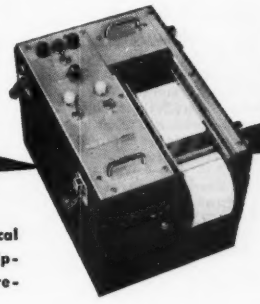

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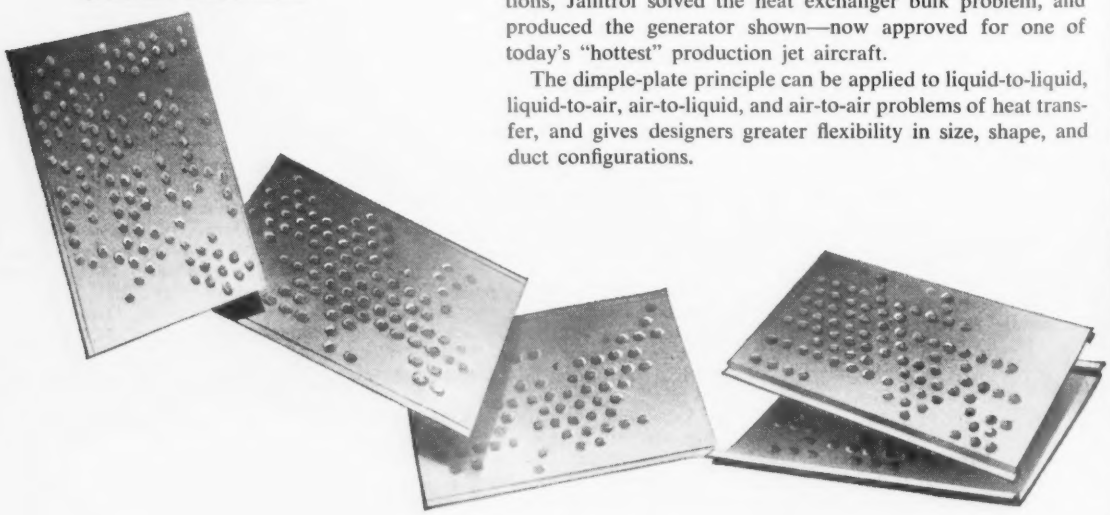

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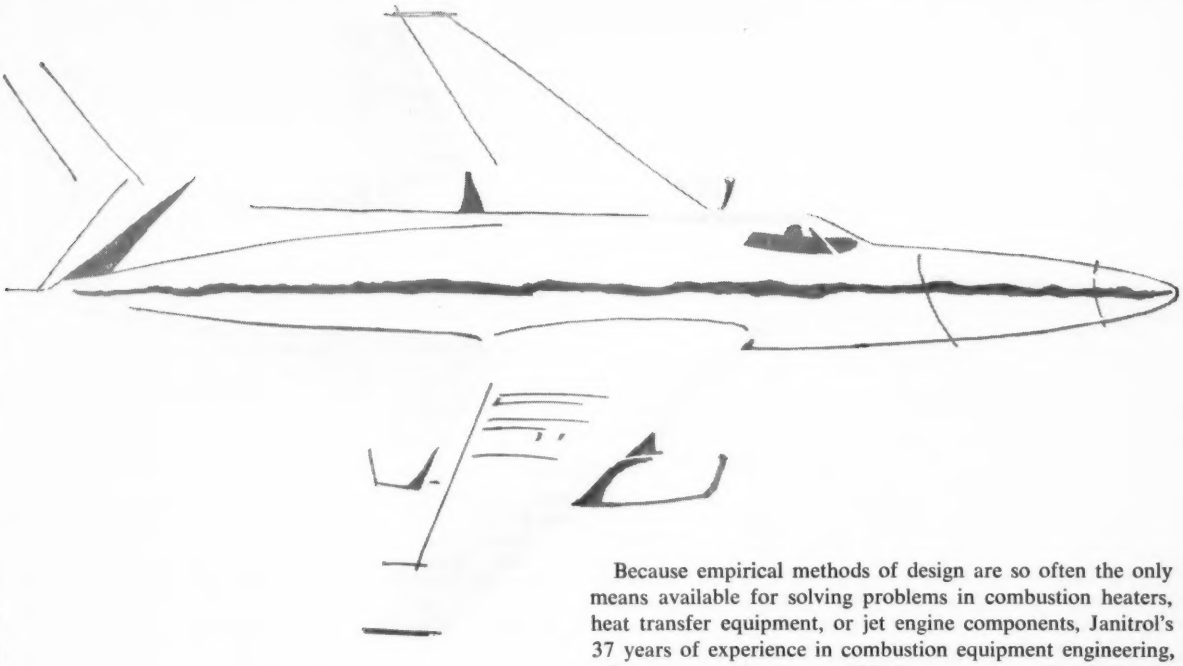

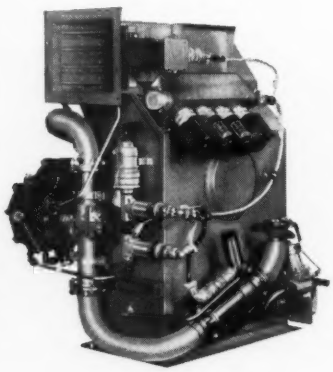

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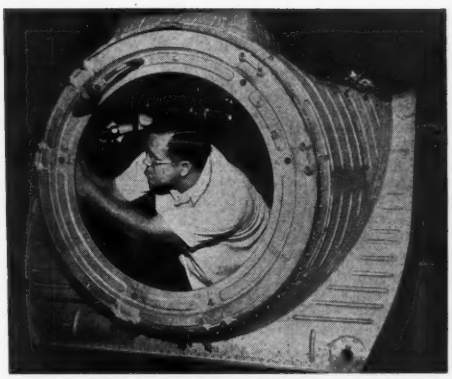

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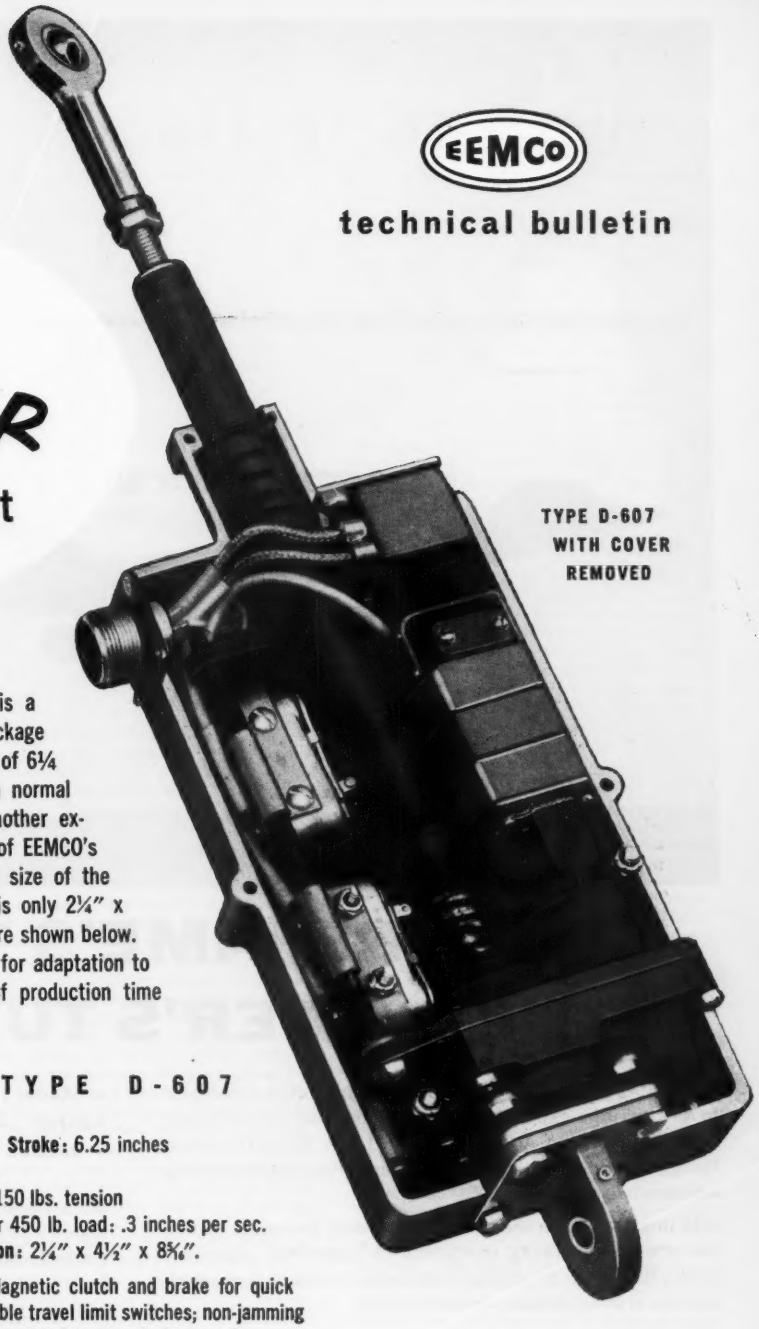


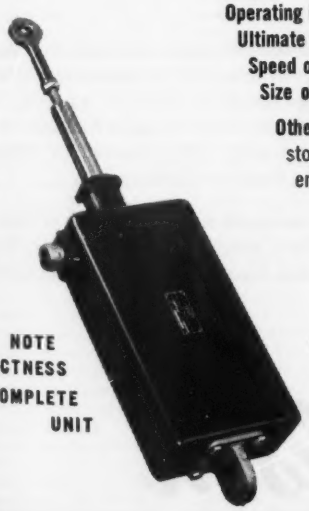
TYPE D-607 WITH COVER REMOVED

EEMCO's new linear actuator, Model D-607 is a compact combination actuator and power package weighing only 4½ pounds. Having a stroke of 6¼ inches at .3 inches per second under a normal operating load of 450 pounds, it is another example of the ingenuity and precision of EEMCO's design and production team. Overall size of the activating section of Model D-607 is only 2¼" x 4½" x 8⅝". Other specifications are shown below. This same design can be altered for adaptation to other uses with a minimum of production time thus assuring early delivery.

SPECIFICATIONS ★ TYPE D-607

Weight: 4.5 pounds **Stroke:** 6.25 inches
Operating load: 450 lbs.
Ultimate static load: 7150 lbs. tension
Speed of stroke under 450 lb. load: .3 inches per sec.
Size of power section: 2¼" x 4½" x 8⅝".

Other features: Magnetic clutch and brake for quick stopping; adjustable travel limit switches; non-jamming end stops; radio noise filter; explosion proof.



NOTE COMPACTNESS OF COMPLETE UNIT

Electrical Engineering and Manufacturing Corp.

4612 West Jefferson Boulevard
Los Angeles 16, California

Designers and producers of motors, linear and rotary actuators

THE AIRFRAME'S THE SAME —THE POWER'S TURBO-PROP

Here is the Convair YC-131C Military Transport, a conversion to Allison Turbo-Prop power of the Model 340 Convair-Liner. Modified under an Air Force contract, the YC-131C is now flying powered by two Allison YT56 Turbo-Prop engines driving Aeroproducts propellers.

With this installation the Air Force is leading the way in testing the practical operating usefulness of Turbo-Prop engines—paving the way for the change from reciprocating to Turbo-Prop engines in transport and logistic aircraft.

Allison Turbo-Prop design and performance characteristics can help today's transports meet tomorrow's advanced operational requirements of:

- **Increased Payloads**
- **Higher Cruising Speeds**
- **Lower Fuel Cost**
- **Less Maintenance Time and Cost**
- **Shorter Take-offs and Landings**
- **Greater Passenger Comfort**
- **Reduced Ground Handling Time**
- **Reduced Crew Fatigue**

Since December 1950, Allison has conducted extensive flight tests with its own Turbo-Liner to exploit the advantages inherent in Turbo-Prop power for transport service. In addition, the Navy is accumulating experience in the Douglas A2D Skyshark and the Convair R3Y Tradewind—also powered by Allison Turbo-Prop engines driving Aeroproducts propellers.

Today that pioneering is paying off in the availability of Turbo-Prop engines and propellers which will enable military and commercial aircraft to carry bigger payloads, farther, faster and more economically.

GM GENERAL MOTORS

Allison

Division of General Motors, Indianapolis, Indiana

Aeronautical Reviews — BOOKS

Book Notes

INSTRUMENTS

Instruments. R.W. Sloley and W. H. Coulthard. 6th Ed. New York, Pitman Publishing Corporation, 1953. 251 pp., illus., diagrs. $7.50.

This book, revised and brought up to date, is now included in "The Aircraft Engineer's Handbook" series, a new series specially designed for Aircraft Engineers qualifying for "M" (Maintenance) Licenses as laid down by the Air Registration Board in the British Civil Airworthiness Requirements (Section L, Licensing). It covers the Category "X" License, and deals with the repair, overhaul, testing, and calibration of aircraft and aero-engine instruments, as well as with the adjustment, installation, and compensation of compasses in aircraft.

MATERIALS

Residual Stresses in Metals and Metal Construction. Edited by William R. Osgood. Prepared for the Ship Structure Committee under the direction of Committee on Residual Stresses, National Academy of Sciences, National Research Council. New York, Reinhold Publishing Corporation, 1954. 363 pp., illus., diagrs. $10.

The scope of the monograph is broad: consideration is given to the origin, magnitude, distribution, etc., of all types of residual stresses existing in a structure or a machine, whether they arise from welding, machining, or any other cause. Experts were asked to contribute to the monograph, and the main body of the present work consists of their papers.

Contents: Effects of Residual Stresses on the Behavior of Structures, F. Campus. Residual Stresses in Welded Pressure-Vessel Manufacture, H. Harris. Some Typical Cases Where Residual Stresses Set Up by Welding Appear to Have Contributed to Ship Structural Failures, D. Arnott. Glossary of Shipbuilding Terms. Residual Stresses as a Factor in Ship Fractures, Admiralty Ship Welding Committee. Some Notes on Typical Residual Stresses Encountered in Welded Ships, P. Ffield. Some Considerations Regarding the Generation and Importance of Residual Welding Stresses, L. E. Benson. Residual Stresses in Welding, W. Spraragen. The Significance of Residual Stresses, C. W. MacGregor. Some Remarks on the Influence of Residual Stresses on the Brittle, Plastic, and Fatigue Behavior of Structures, P. P. Bijlaard. The Influence of Residual Stresses on the Behavior of Ductile Structures, M. R. Horne. Shakedown of Elastic-Plastic Structures, P. G. Hodge, Jr. The Inclusion of Initial Residual Stresses in Hodge's Elementary Example and a Numerical Illustration. Microstresses Originated by Gas Inclusions, N. J. Petch. The Effect of Residual Stresses on High-Speed Impact Resistance, J. Miklowitz. Correlation of Residual Stresses with Fatigue Strength of Machine Elements and Related Phenomena, O. J. Horger and H. R. Neifert. Effect of Residual Stresses on the Failure of Engineering Materials, D. Rosenthal. Residual Stresses and Static Fracture—Comments on "Effect of Residual Stresses on the Failure of Engineering Materials" by D. Rosenthal and W. M. Baldwin, Jr. Author's Reply to Baldwin's Comments on the "Effect of Residual Stresses on the Failure of Engineering Materials," D. Rosenthal. Measurement of Residual Stress, D. Rosenthal. Residual Stresses Associated with Lattice Strain, G. B. Greenough. Precautions to Be Used in the Measurement and Interpretation of Residual Stresses by X-Ray Technique, W. S. Hyler and L. R. Jackson. Complete Determination of the State of Residual Stress in Solid and Hollow Metal Cylinders, H. Bühler. Determination of Residual Stresses below the Surface, W. Soete and R. Vancrombrugge. Summary, Bibliographical Sources, and Index.

Statics and Strength of Materials, An Integrated Presentation. Roland H. Trathen. New York, John Wiley & Sons, Inc., London, Chapman & Hall, Ltd.; 1954. 506 pp., diagrs. $7.50.

Professor Trathen departs from the usual mechanics sequence and from existing texts to unify the study of statics and strength of materials as a textbook for a first course. The flexible arrangement of his book allows adjustment to teaching demands of various instructors and curricula. The author makes a definite attempt to utilize the mathematical knowledge the reader has acquired. The analogy between certain mathematical equations is used to tie seemingly unrelated topics together. There are over 500 problems included in the book, and these are designed to check the reader's understanding of basic concepts. Practice problems have been placed at the end of the book so as not to interfere with orderly presentation of theory. Extensive use is made of the free body concept. Care is taken in explaining sign conventions, and nomenclature conforms to the recommendations of the American Standards Association.

A Symposium on the Plastic Deformation of Crystalline Solids; Mellon Institute, Pittsburgh, May 19, 20, 1950. Under the Joint Sponsorship of the Carnegie Institute of Technology and the Department of the Navy, Office of Naval Research. Washington, Office of Technical Services, 1950. 223 pp., diagrs., figs. $3.50.

Contents: Foreword, J. S. Koehler. The Theory of Plastic Flow in Single Crystals, Frederick Seitz. Influence of Plastic Flow on the Electrical and Photographic Properties of the Alkali Halide Crystals, Frederick Seitz. Multiplication Processes for Slow-Moving Dislocations, F. C. Frank and W. T. Read, Jr. Creep of Zinc Crystals, E. P. T. Tyndall. The Yield Point in Single Crystal and Polycrystalline Metals, A. H. Cottrell. The Lamellar Nature of Slip and Its Implications, T. H. Blewitt and J. S. Koehler. The Origin of Dislocations, F. G. Frank. The Experimental and Theoretical Results of Plasticity at Normal Speeds of Strain, U. Dehlinger. X-Ray Diffraction Studies of Cold Work in Metals, B. E. Warren and B. L. Averbach. Dislocation Models of Crystal Grain Boundaries, W. T. Read and W. Shockley. The Resultant Content of Dislocations in an Arbitrary Intercrystalline Boundary, F. C. Frank. A Study of Amplitude-Dependent Internal Friction Arising from the Motion of Dislocations in Single Crystals of Copper, A. S. Nowick. Decrement and Young's Modulus Measurements on Single Crystals of Copper and Lead, J. Marx and J. S. Koehler. Structures of Cold-Worked Metals as Deduced from Anelastic Measurements, T. S. Ke and C. Zener. The Plasticity of Polycrystalline Solids, Bruce Chalmers. Wanted: Experimental Support for Theories of Plastic Flow, J. C. Fisher and J. H. Hollomon. A Theory of Deformation Textures in Face-Centered Cubic Metals, Walter R. Hibbard, Jr. The Crystallographic Aspect of Slip in Body-Centered Cubic Single Crystals, A. Opinsky and R. Smoluchowski.

MATHEMATICS

Theory of Games and Economic Behavior. John Von Neumann and Oskar Morgenstern. 3rd Ed. Princeton, N.J., Princeton University Press, 1953. 641 pp., figs. $10.

This book gives a detailed account of the theory of games, with numerous applications to characteristic games of strategy. No technical knowledge of any definite part of mathematics is required, but the reader should be familiar with the mathematical way of reasoning, procedure, and notation. Some applications to economic and social theory are made—discussions of the concepts of parallel or opposite interest, perfect or imperfect information, free rational decision or chance influences, as well as of the problems of the structure of certain markets. This revised edition of *Theory of Games and Economic Behavior* contains a new preface citing the major studies on the theory of games which have developed from this book, and referring to the published bibliographies on the subject.

Chambers's Shorter Six-Figure Mathematical Tables. L. J. Comrie. New York, Chemical Publishing Co., Inc., 1954. 387 pp. $6.50.

This volume has been issued to meet the demand for a single volume of about 400 pages rather than the two volumes of about 1,200 pages which were prepared a decade ago under the title "Chamber's Six-Figure Mathematical Tables." Many pages have been taken from one or the other of the parent volumes; others have been reset with a wider interval of argument. Among the tables omitted are trigonometrical functions in degrees and decimals, both natural and logarithmic. The author, who is head of Scientific Computing Service, Ltd., has concentrated on a collection of general mathematical functions since

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many specialized requirements are apparently amply met by a multiplicity of tables.

PERSONNEL

Proceedings of a Conference on the Utilization of Scientific and Professional Manpower; Held October 7–11, 1953, at Columbia University. National Manpower Council. New York, Columbia University Press, 1954. 197 pp. $3.50.

Contents: 1, Issues in the Utilization of Scientific and Professional Manpower, James D. Zellerbach. 2, An Economist's View of the Manpower Concept, Kenneth E. Boulding. 3, Manpower Utilization from the Point of View of Top Administration, Frank Pace, Jr. 4, Technicians and the Utilization of Professional Manpower, Seymour L. Wolfbein. 5, Engineering Personnel; Some Thoughts on the Utilization of Engineers, George M. Maverick. 6, Medical Personnel; Problems and Potentialities of Using Premedical Personnel to Insure the Most Effective Utilization of Medical Personnel, Marcus D. Kogel. 7, Teaching Personnel; More Effective Utilization of Teachers, Henry Chauncey. 8, Summary of Conference Findings. Conference Discussion of Findings. Appendix A, Conference Program. Appendix B, Conference Participants. Index.

REFERENCE WORKS

The Aircraft of the World. William Green and Gerald Pollinger. Garden City, N.Y., Hanover House, 1954. 160 pp., illus., diagrs. $5.95.

Aircraft of the World describes in detail and illustrates all aircraft known to be flying throughout the world at the time of going to press. Exceptions have been made in the case of early aircraft that appear rarely at flying displays as curios of the past and specialized midget racing aircraft that have appeared at times in the United States. In the case of manufacturers' series of aircraft of generally similar appearance, representative models have been selected. Aircraft descriptions are arranged by a system of structural grouping which brings together aircraft of similar appearance. An accurate and detailed cross-index provides rapid reference to aircraft by name, service designation, or manufacturer. Textual material gives brief specifications, performances, and history. Generously illustrated, this volume includes many hundreds of excellent photographs and a unique collection of detailed three-view silhouettes of the aircraft of twenty-five nations. This extensive collection of illustrations will offer ready comparison for the first time of all aircraft flying today, whether it be a veteran of the mid-twenties plying an obscure route in Bolivia or Uruguay, or the latest supersonic fighter prototype.

William Greene has had a wide experience as an aviation journalist; Gerald Pollinger is Honorary Secretary of The Aircraft Recognition Society and serves on committees of other aeronautical societies. Both have served with the Royal Air Force. This volume should prove to be an invaluable source of reference to those interested in the design, performance, and history of jet- and propeller-driven aircraft, flying boats, and helicopters.

RESEARCH

An Introduction to Scientific Research. E. Bright Wilson, Jr. New York, McGraw-Hill Book Company, Inc., 1952. 375 pp., figs. $6.

This book is an attempt to collect in one place and to explain as simply as possible a number of general principles, techniques, and guides for procedure which successful investigators in various fields of science have found helpful. The emphasis is on the practical rather than the philosophical or psychological aspects. The book is intended chiefly for students beginning research and for those more experienced research workers who wish an introduction to various topics that were not included in their training. To that end, notes and references to detailed and expanded treatments in the literature are given at the ends of chapters.

Contents: (1) The Choice and Statement of a Research Problem. (2) Searching the Literature. (3) Elementary Scientific Method. (4) The Design of Experiments. (5) The Design of Apparatus. (6) The Execution of Experiments. (7) Classification, Sampling, and Measurement. (8) The Analysis of Experimental Data. (9) Errors of Measurement. (10) Probability, Randomness, and Logic. (11) Mathematical Work. (12) Numerical Computations. (13) Reporting the Results of Research. Conclusion. Index.

ROTATING WING AIRCRAFT

Helicopter Rating. Charles A. Zweng. North Hollywood, Calif., Pan American Navigation Service, 1954. 325 pp., illus., diagrs. Unbound, $5.00; Bound, $6.50.

This manual is an attempt to present a practical guide to the relatively new skill of piloting helicopters. The purpose of this training book is to prepare students for the written examinations and, to a certain extent, the oral and/or practical phases. The text is composed of the material covered in the CAA examinations, as well as a considerable amount of fundamental helicopter data that will be of help in performing the duties of the helicopter pilot and instructor. In addition to being a valuable text for those whose transition will be from the conventional-type airplane to the helicopter, it will serve as a basic introduction to helicopters for those who have not had previous flight training, and therefore a valuable book for any general library.

Contents: 1, The Helicopter Pilot Rating. 2, Rotary Wing Aircraft: History and Development. 3, Helicopter Aerodynamics and Nomenclature. 4, Flying the Helicopter. 5, Helicopter Operation. 6, Civil Air Regulations. 7, Helicopter Instrument Flying. 8, Preparation for the Government Written Examinations. 9, Preparation for the Government Flight Examinations. 10, Representative Multiple-Choice Questions and Answers for the Helicopter Pilot Rating. Index.

Typical Helicopter Performance Calculation. R. J. Harris, L. H. Sloan, and K. W. Ulrich. (Rotary Aircraft Series, No. 2.) Morton, Pa., Rotorcraft Publishing Committee, 1952. 43 pp., figs. $1.25.

The helicopter chosen for this sample calculation is a hypothetical single-rotor design of the cargo utility type. Rotor diameter is specified as 52 ft.; gross weight range, 5,000 to 7,000 lbs.; take-off power, 600 b.hp. at 2,250 r.p.m. at sea level. Some of the calculated performances are: maximum level flight speed, 118 m.p.h.; average cruising speed, 84 m.p.h.; and range, 320 miles. Certain oversimplifications have been used, but only in order to place more emphasis on the overall solution of the performance analysis problem. The authors state that the simplifications employed are suitable for preliminary analysis and have proved acceptable in practice. They also suggest where practical refinements can be made for final or detailed performance analysis.

STRUCTURES

Principles of Experimental Stress Analysis. Mark B. Moore. New York, Prentice-Hall, Inc., 1954. 146 pp., illus., diagrs. $4.00.

In preparing this text, the author has tried to include only that material directly concerned with the basis of experimental technique used in current work. The text endeavors to reflect the trend toward the use of electrical strain gages, and the use of mathematics has been minimized. It is assumed that the student has an adequate background in the mechanics of materials and in the properties and applications of engineering materials. Problem and laboratory experiments are given, and there are several lists of selected references for more detailed study. The author is an Associate Professor of Mechanical Engineering at Rutgers University.

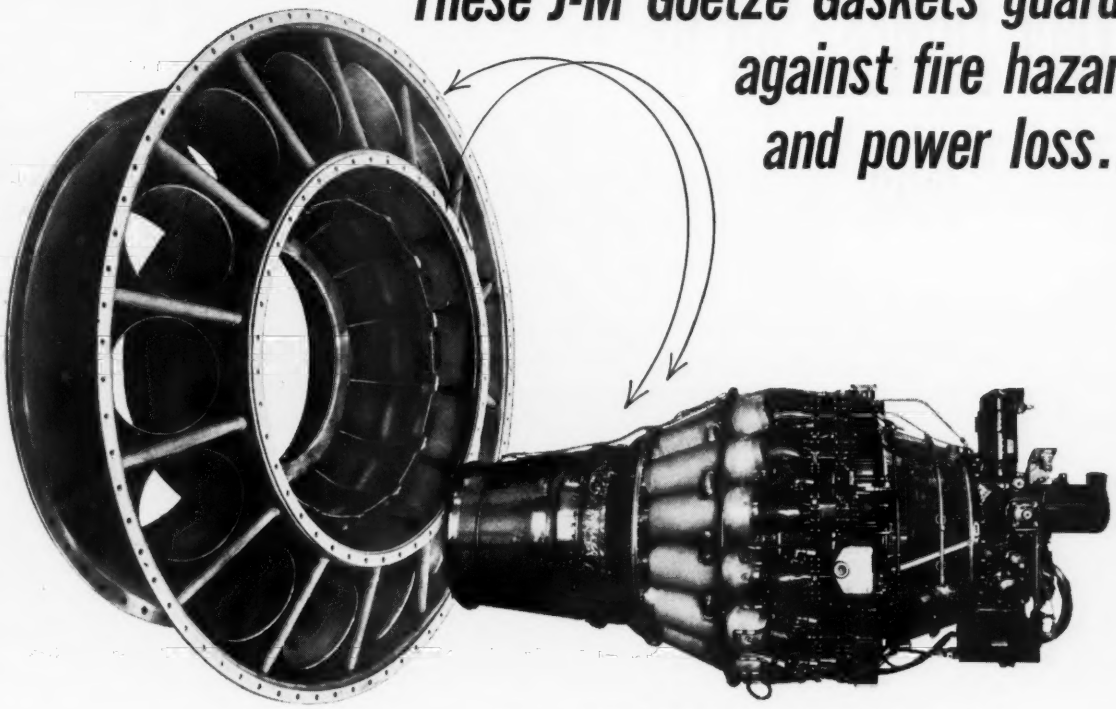
Contents: 1, Introduction. 2, Basic Stress-Strain Relationships. 3, Failure of Engineering Materials. 4, Stress Analysis, or Is It Strain Analysis. 5, Mechanical and Optical Strain Measuring Devices. 6, Electric Strain Gages. 7, Plane Stress-Strain Relationships: Strain in Two Directions. 8, Strain Gage Forms and Strain Rosettes. 9, Dynamic Strain Measurement. 10, Brittle Coatings. 11, Photoelastic Strain Measurements. 12, The Membrane Analogy. 13, Laboratory Experiments: (a) Laboratory Work on the Causes of Failure; (b) Laboratory Work on Mechanical Strain Measurements; (c) Electric Strain Gages; (d) Brittle Coatings; (e) Photoelastic Stress Analysis Methods. Index.

Proceedings of the Society for Experimental Stress Analysis, Vol. 11, No. 2. Edited by C. V. Mahlmann and W. M. Murray. Cambridge, Mass., Society for Experimental Stress Analysis, 1954. 222 pp., illus., diagrs.

Contents: Control and Programmings of a 200,000-Pound Fatigue Machine, H. C. Roberts and V. J. McDonald. Letter to the Editor: Deformation Measurements with Centimeter Radio Waves, C. W. Tolbert and A. W. Straiton. Internal Stress Gauges for Cementitious Materials, Y. C. Loh. Simplified Measurement of Residual Stress, J. L. Waisman and A. Phillips. Network Representation of Elastic Problems in Cylindrical Coordinates, W. A. Gross and W. W. Soroka. Experimental Stress Determination within a Metal during Plastic Flow, E. G. Thomsen and J. T. Lapsley, Jr. Theory and Techniques of Calibration for Structural Flight Load Measurement, L. Rogin. Plastic Models for Vibration Analysis, G. O. Sankey. Experimental Investigation of the Blast Loading on an Idealized Structure, J. Penzien. A New Dynamic Creep Testing Machine, Y. H. Pao and J. Marin. The Prediction of Dynamic Performance of Full-Scale Gun Turrets from Static Tests of Small-Scale Models, E. Wenk, Jr. Ground Shock and Building Motions Produced by a Quarry Blast, G. W. Housner, D. E. Hudson and J. L. Alford. Letter to the Editor: Application of Silver-Painted Slip Rings for Strain Gage Circuits, D. K. Wright, Jr., and J. R. Jeromson, Jr. Long-Time Strain Measurements in Reinforced Concrete, F. R. Beyer and M. J. Lebow. Crack Density Studies in "Stresscoat," A. J. Durelli and S. Okubo. Photoelastic Analysis of Reinforced Stress Raisers, J. B. Mantle. Improved Brittle Coatings for Use under Widely Varying Temperature Conditions, F. N. Singdale. Stress Concentration Factors for a Single Notch in a Flat Bar in Pure and Central Bending, M. M. Leven and M. M. Frocht. A Six-Unit Universal Creep Testing Machine for Plastics, Y. H. Pao and J. Marin.

Proceedings of a Panel Discussion on the Interpretation and Application of Test Data: Opening Remarks, S. A. Gordon. Relation between Stress Analysis and Fatigue of Metals. Interpretation of Creep and Long-Time Test Data, J. Marin. High Temperature Test Data, A. W. Brunot. Interpretation and Application of Inspection Test Data, P. V. Faragher. Statistics and Planing Tests at Elevated Temperatures.

These J-M Goetze Gaskets guard against fire hazard and power loss...



Arrows point to J-M Goetze metallic gaskets on the inner and outer annulus, and their approximate location on the J33 turbojet engine turbine frame.

...on powerful turbojet engines like the J33

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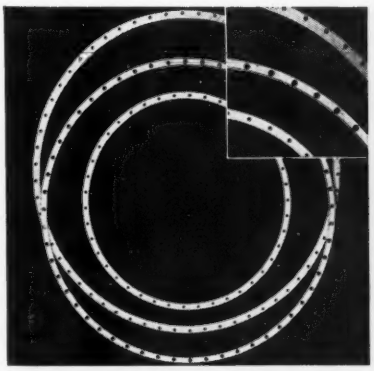

Close-up of J-M Goetze metallic gaskets used as inner and outer annulus gaskets on jet engine turbine frame.

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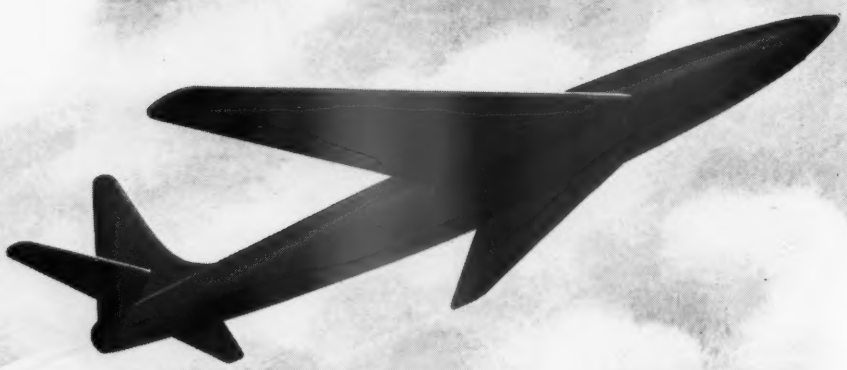

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Personnel Opportunities

This section is for the use of individual members of the Institute seeking new connections and organizations offering employment to Aeronautical specialists. Any member or organization may have requirements listed without charge by writing to the Secretary of the Institute.

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Project Engineer—Expanding Southern California development firm requires engineer with proved administrative talents for position with excellent future in management. Must be interested and capable of working in and supervising design and testing in diverse branches of applied aerophysics research. Background and experience must justify unsupervised participation in important and interesting projects related to aircraft and missile stress, preliminary design, aerodynamics, and the design of small mechanical and electromechanical devices. Ability and inventiveness required in generating proposals for research and development applications, especially in supersonic free-flight dynamics testing. Excellent salary. Send detailed experience record, description of outside activities, and transcript of collegiate record, together with samples of reports, drawings, inventions, writings, or other scientific contributions. This is an excellent chance for a young man now in a junior position blocked by seniority. Send replies to: Aerolab Development Company, 330 West Holly St., Pasadena 3, Calif.

Aircraft Performance Engineer—GS-11 $5,940 per annum; GS-9, $5,060 per annum. Calculation and compilation of engineering data for use in aircraft characteristic summary sheets; responsibility for obtaining and evaluating latest configuration data on new aircraft; perform mathematical calculations on special aerodynamic problems. Applications may be submitted on Standard Form 57, Application for Federal Employment, to Department of the Navy, Bureau of Aeronautics, Personnel Division, Attention: PE-212, Washington 25, D.C. Standard Form 57 is available at U.S. Post Offices, or may be obtained by writing to the Personnel Division, Bureau of Aeronautics. Visitors to the Washington area may call at Room 3909 of the Main Navy Building, 19th and Constitution Ave., N.W., Washington, D.C.

Academic Positions—The University of Toledo has several openings in the Department of Engineering Mechanics, with ranks from instructor to associate professor or professor. Applicants should have advanced degree(s) and, preferably, they should have teaching and industrial experience as well. For the higher ranking appointment, a thorough background in modern experimental techniques applied to structural analysis, elasticity, and plasticity is required. Duties include teaching of undergraduate and graduate courses and the development of laboratories in strength of materials and fluid mechanics and dynamics. Applicants should write to Prof. R. M. Rosenberg, Department of Engineering Mechanics, University of Toledo, Toledo 6, Ohio, and they should state their qualifications in the first communication.

Aeronautical Research Personnel—Cornell Aeronautical Laboratory, Inc., an affiliate of Cornell University, has the following research and development opportunities: **Wind-Tunnel Operations**—To assist in the planning of test programs and instrumentation for model tests and airflow calibrations in our 8½- by 12-ft. variable-density tunnel. **Flight Research**—To assist in the analysis and project execution of dynamic stability and control programs utilizing full-scale aircraft. Must have a good grasp of rigid body dynamics. **Aeroelasticity**—Analytical and experimental research in aircraft flutter phenomena. Large scale wind-tunnel models are designed and tested to provide data for comparison with existing aeroelastic theories. **Propulsion**—Must be well versed in both theory and practical applications. Would join a composite design group where continual studies of advanced-type aircraft and missiles are undertaken. Address inquiries to W. S. Diefenbach, Employment Manager, Cornell Aeronautical Laboratory, Inc., Buffalo 21, N.Y.

Engineers—Openings in rocket launcher and recoilless weapons design. Need qualified personnel in the fields of engineering, mathematics metallurgy, chemistry, and ballistics. Excellent opportunity to become affiliated with one of the finest old Arsenals in existence. Write or send application of Standard Form 57, which can be obtained at your Post Office, to Commanding Officer, Rock Island Arsenal, Rock Island, Ill., Attention: Civilian Personnel Division.

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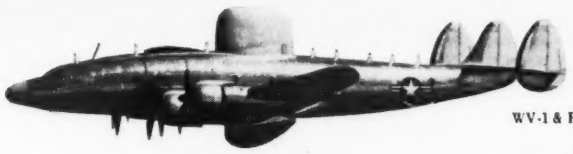

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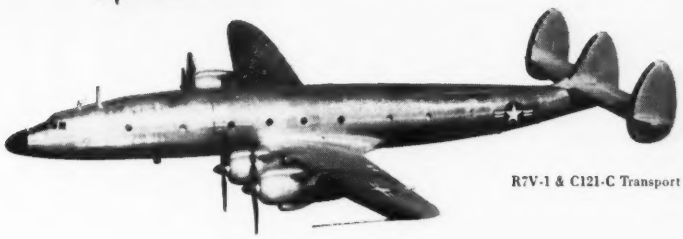

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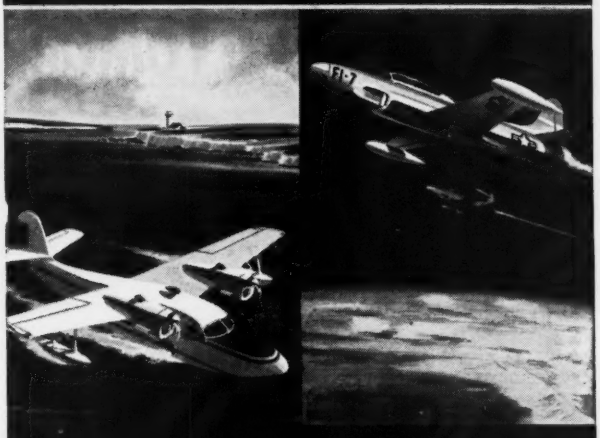

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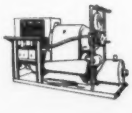

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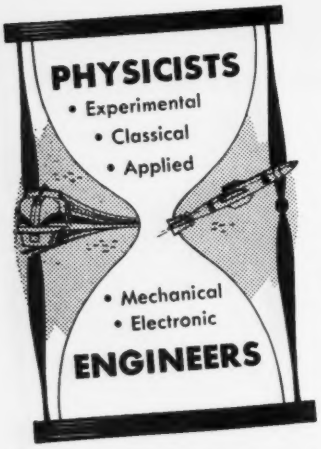

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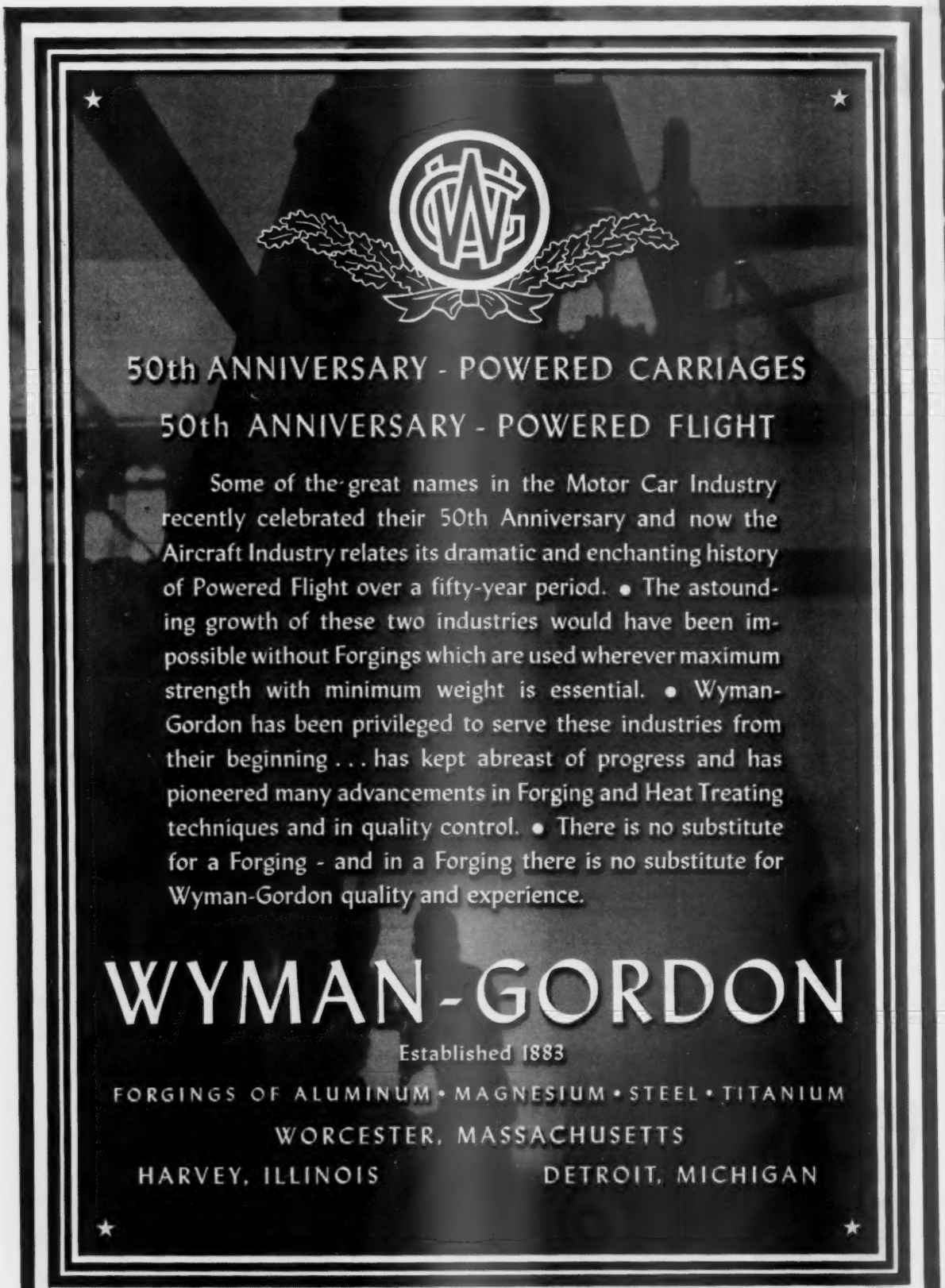

50th ANNIVERSARY - POWERED CARRIAGES

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Some of the great names in the Motor Car Industry recently celebrated their 50th Anniversary and now the Aircraft Industry relates its dramatic and enchanting history of Powered Flight over a fifty-year period. • The astounding growth of these two industries would have been impossible without Forgings which are used wherever maximum strength with minimum weight is essential. • Wyman-Gordon has been privileged to serve these industries from their beginning . . . has kept abreast of progress and has pioneered many advancements in Forging and Heat Treating techniques and in quality control. • There is no substitute for a Forging - and in a Forging there is no substitute for Wyman-Gordon quality and experience.

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AERONAUTICAL REVIEWS

New Products and Product Literature of interest to IAS members

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AIRCRAFT MATERIALS & PROCESSES

Protective Coating for Aluminum. Folder describes Brush "Alodine" No. 1200. **American Chemical Paint Co., Ambler, Pa.**

Thermostat Metal Strip and Fabricated Bimetal Elements. Available in coils or cut lengths in thicknesses of 0.001 in. and over, in widths ranging from 1/16 in. to 5 in., with thickness tolerances held as close as ±0.00015 in. **American Silver Co., 36–07 Prince St., Flushing, N.Y.**

Properties of Ternalloy. Eight-page brochure, describes aluminum base alloys. **Apex Smelting Co., 2537 W. Taylor St., Chicago 12, Ill.**

Catalic Air-Cure Coating. This protective coating is impervious to all known aircraft hydraulic fluids, petroleum and synthetic engine oils, alcohol, esters and petroleum hydro-carbons. **Finch Paint & Chemical Co., Torrance, Calif.**

"Tungstide Metal-Cladding" Coating. When applied to any surface at room temperature, it imparts hardness and abrasion-resistance, and is self-lubricating. **The Lockrey Co., Southampton, N.Y.**

3M Adhesives, Coatings and Sealers. This booklet classifies materials by Government specification requirements. **Minnesota Mining & Mfg. Co., Adhesives & Coatings Div., 411 Piquette Ave., Detroit 2, Mich.**

Paper-Base Electrical Grade Plastic. Eliminates the difficult machining properties frequently encountered with the present series of melamine plastics. **National Vulcanized Fibre Co., Wilmington, Del.**

"Here's Rogers Again." Booklet describes originators and fabricators of impact phenolics and fibrous specialty materials. **Rogers Corp., Goodyear, Conn.**

Ceramic Coatings for Protecting Metals. Eight-page descriptive brochure. **Solar Aircraft Co., Dept. 701, San Diego 12, Calif.**

Titanium Tubing. Eight-page bulletin No. 42, describes properties, applications, and advantages. **Superior Tube Co., 1503 Germantown Ave., Norristown, Pa.**

AIRCRAFT PARTS & EQUIPMENT

Aircraft Electrical & Radio Equipment. Thirty-five page descriptive catalog No. 21d. **Air Associates, Inc., Dept. AD, Teterboro, N.J.**

"ANGLgear" Standardized Right Angle Bevel Gear Units. Descriptive four-page folder. **Airborne Accessories Corp., 1414 Chestnut Ave., Hillside, N.J.**

ARC-16706 Course Indicator. For use with A.R.C. type 15D VOR Airborne receiving equipment; combines functions of a cross-pointer meter and course selector in one unit. **Aircraft Radio Corp., Boonton, N.J.**

RDR-1 Airborne Radar. Enables pilot to see instantly the position, intensity, and extent of a storm within a range of 150 miles. **Bendix Radio Div., 2120 N. Charles St., Baltimore 18, Md.**

Aircraft Cables & Assemblies. Technical reference folder describes new swaging method. **Bergen Wire Rope Co., Aircraft Div., Lodi, N.J.**

Self-Locking Nuts. Fifty-seven page specifications catalog. **Boots Aircraft Nut Corp., Norwalk, Conn.**

SR-43 Actuator Motor. For such applications as low- or high-speed, linear- or rotary-actuator mechanisms. **Dalmotor Co., 1398 Clay St., Santa Clara, Calif.**

Lightweight Elastic Stop Nuts. For weight savings throughout the whole range of aircraft locknut applications. **Elastic Stop Nut Corp. of America, Union, N.J.**

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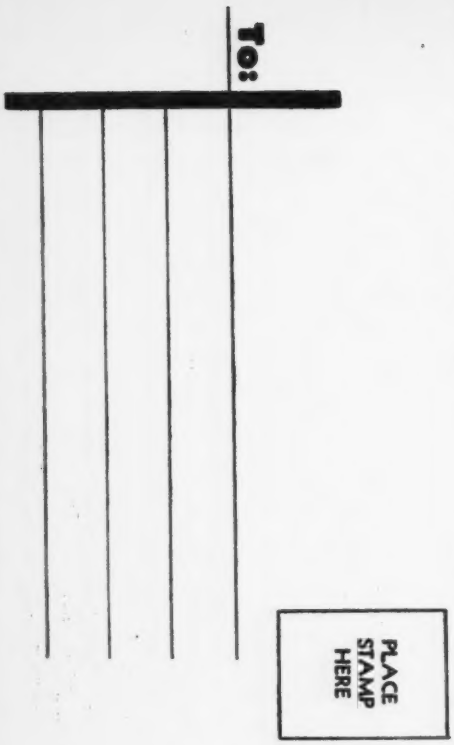

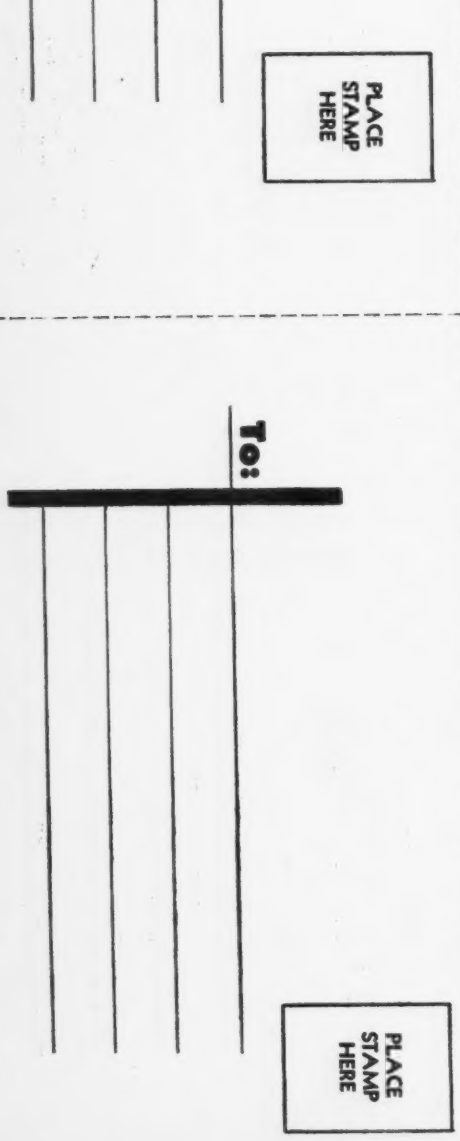

Model PX-2 Lightweight Permanent Magnet Separator. Provides for the removal of very fine steel particles that may wear off moving parts in hydraulic fluid systems. **S. G. Frantz Co., Trenton, N.J.**

Remote Controlled Tail Turret System. Designed for the Air Force's Boeing B-47E, it can track and shoot down unseen targets. **General Electric Co., Schenectady 5, N.Y.**

Model S-12 Cartridge-Type Starter. This solid propellant unit permits plane to carry its own engine starting power for fast starts. **General Electric Co., Schenectady 5, N.Y.**

Miniature High Torque Rotary Actuator. For special applications, including low backlash, waterproofing, limit switches, dynamic braking, slip clutches, follow-up potentiometers, speed governors, etc. **Globe Industries, Inc., 1784 Stanley Ave., Dayton 4, Ohio.**

Facilities Brochure. Twenty-page brochure entitled, "Ready Room." **Goodyear Aircraft Corp., Akron 15, Ohio.**

"4-D" High Pressure Air Compressor. This 11-lb. unit has an envelope size of 10 in. and delivers 4 cu.ft. of free air per min. (at sea level) compressed to 3,000 lbs. per sq.in. **Walter Kidde & Co., Inc., Belleville, N.J.**

Vibration Damper. Provides the additional damping required in many vibration control systems. **Lord Mfg. Co., Erie, Pa.**

Screw Machine Products. Fourteen-page descriptive brochure. **The New Britain Machine Co., New Britain, Conn.**

Hydraulic Non-Interflow Rotary Plate Valves. Incorporates two optically true hardened steel plates, controlled by a Bendix development, which virtually eliminates leakage between ports. **Pacific Div., Bendix Aviation Corp., 11600 Sherman Way, North Hollywood, Calif.**

Variable-Area Fuel Nozzle. Features include: ability to handle contaminated fuels, excellent atomization, maintenance of full fuel manifold, and accurate nozzle metering. **The Parker Appliance Co., Engine Accessories Div., Section 303-C, 17325 Euclid Ave., Cleveland 12, Ohio.**

¾ In. Low Pressure Regulator. Is capable of passing 600 cu.ft. per hour 0.6 specific gravity gas at 4 in. WC pressure drop, and features accurate regulation to within $^{5}/_{100}$ in. WC throughout its full range of operating pressures. **The Paulsen-Johnson Co., 1647 Eddy Rd., Cleveland 12, Ohio.**

"Sel-Lok" Spring Pin. Four-page descriptive folder. **Standard Pressed Steel Co., Box No. 869, Jenkintown, Pa.**

Model 22 Reference Gyro for Missiles. Designed to withstand extreme acceleration and shock up to 60*g*. **Summers Gyroscope Co., 2328 Broadway, Santa Monica, Calif.**

Model 205 Position Servo Actuator. Features a torque-to-inertia ratio of 200,000 rad. per sec.^{2} coupled with an acceleration time constant of 10 millisec. **Summers Gyroscope Co., 2328 Broadway, Santa Monica, Calif.**

Leak-Proof Quick-Seal Hose Coupling. Sixteen-page descriptive booklet. **Titeflex, Inc., Hendee St., Springfield, 4, Mass.**

Model 1524 Rotary Actuator. For aviation, electronic, automatic control, and original equipment applications. **Western Gear Works, P.O. Box 182, Lynwood, Calif.**

ELECTRONIC & ELECTRICAL EQUIPMENT

TQ Miniature Telephone-Type DC Relay. This unit measures 94 cu.in. in size and weighs 1.2 oz., and is available in contact combinations up to 6PDT. **Advance Electric & Relay Co., 2435 N. Naomi St., Burbank, Calif.**

High Temperature Servo Motors. These motors operate in regions of 160°C. (320°F.) **American Electronic Mfg., Inc., 9503 W. Jefferson Blvd., Culver City, Calif.**

Model 255 & 355 Contact Meter-Relay. These instruments must stand a 50*g* shock and vibration of 10–55 cycles per sec., 0.03 sec. amplitude. **Assembly Products, Inc., P.O. Box 191, Chagrin Falls, Ohio.**

Fractional Horsepower Motors. Available in either 2- or 4-pole synchronous or induction types in ratings of $^{1}/_{2,000}$, $^{1}/_{1,000}$, or $^{1}/_{750}$ hp., with power dissipated within safe temperature rise. **The George W. Borg Corp., 120 S. Main St., Janesville, Wis.**

Miniature D.C.-A.C. Synchronous Inverter. This "Syncroverter" switch is capable of converting low-power d.c. signals to alternating voltages. **The Bristol Co., Waterbury 20, Conn.**

Model 3015 Miniature Magnetic Pick-up. For applications where weight is limited and space restricted, such as rockets and guided missiles. **Electro Products Laboratories, Inc., 4501 N. Ravenswood Ave., Chicago 40, Ill.**

Size 51 Servo Motor With Tachometer Generator. Applications include guided missiles, gun sights, aircraft controls. **G-M Laboratories Inc., 4300 N. Knox Ave., Chicago 41, Ill.**

High Speed Multichannel Sampling Switch. Employs contact plates molded with mica filled resin. **General Devices, Inc., P.O. Box 253, Princeton, N.J.**

Glass-to-Metal Sealing. Twenty-page descriptive catalog. **The Hermaseal Co., Inc., Elkart, Ind.**

"ROTA-MAG" Voltage Regulator. Applications include production line testing, engine starting, and pre-flight check-out. **Hufford Machine Works, Inc., Electronics Div., 2201 Carmelina Ave., Los Angeles 64. Calif.**

Electronic Components. Thirty-six page catalog No. R-200, describes yokes, coils, and transformers. **I-T-E Circuit Breaker Co., 19th & Hamilton Sts., Philadelphia 30, Pa.**

Model BD4 "Ledex" Rotary Solenoid. This unit measures 1 9/16 in. in diameter. **G. H. Leland, Inc., 123 Webster St., Dayton 2, Ohio.**

60 & 400 CPS Magnetic Servo Amplifiers. Descriptive bulletin S235-1-54. **Magnetic Amplifiers, Inc., 632 Tinton Ave., New York 55, N.Y.**

Model ME/PP-11 200 Watt Frequency Stabilized Power Supply. Designed to provide a stable 60 cycle per sec., 115- or 230-volt source to operate frequency critical devices requiring up to 200 watts, in areas where the line frequency is not dependable. **Maryland Electronic Mfg. Corp., Dept. 3, College Pk., Md.**

RCA-6383 "Flyweight" Power Triode Electron Tube. This 8-oz. unit is designed for airborne communications use. **Radio Corp. of America, 30 Rockefeller Plaza, New York 20, N.Y.**

"Seletron" Selenium Rectifiers. Twenty-four page descriptive catalog No. 177. **Radio Receptor Co., Inc., Sales Dept., 251 W. 19th St., New York 11, N.Y.**

Type W Bimetal Strip Thermostats. Descriptive bulletin No. L-6395. **Stevens Mfg. Co., Inc., 69 S. Walnut St., Mansfield, Ohio.**

Subminiature Snap-Acting Switch. This tiny unit measures 25/32 by 23/64 by 1/4 in. and is available in plain or leaf-actuator styles. **Unimax Switch Div., The W. L. Maxson Corp., 460 W. 34th St., New York 1, N.Y.**

VA-94 Ku-Band Reflex Klystron. Designed for missile and radar applications in the frequency range of 16 to 17 kmc. **Varian Associates, 611 Hansen Way, San Carlos, Calif.**

Union "KP" Relay. For use in complicated circuits where exceptional sensitivity and high operating speeds are essential. Bulletin No. 1002. **Union Switch & Signal Div., Westinghouse Air Brake Co., Pittsburgh 18, Pa.**

Quick Selector. 112-page catalog, describes motors, controls, safety switches, circuit breakers, dry type transformers, and application data. **Westinghouse Electric Supply Co., 2950 Northern Blvd., Long Island City, N.Y.**

PRODUCTION & MAINTENANCE EQUIPMENT

Model SD6 Trutorq Screw Driver. Designed to operate in the torque ranges generally required for machine screws. **Airdraulics Engineering Sales Co., Allendale, N.J.**

Portable High Pressure Air Compressor. For aircraft maintenance where a portable supply of high pressure compressed air might be needed. **The Cornelius Co., 550 39th Ave. N.E., Minneapolis 21, Minn.**

Vertical Broaching Machine With Electro-Mechanical Drive. Designed primarily for high-production broaching of large aircraft engine turbine buckets. **The Lapointe Machine Tool Co., Hudson, Mass.**

"Aids in Selecting Die-Less Duplicating Equipment." Eight-page booklet, describes Di-Acro precision metalworking machines. **O'Neil-Irwin Mfg. Co., 504 Eighth Ave., Lake City, Minn.**

Tank Can. For packaging wing tanks; each can contains six 450-gal. type II jet wing tanks. **Royal Jet, Inc., Alhambra, Calif.**

RESEARCH & TEST EQUIPMENT

Mark 111 Anthropomorphic Test Dummy. Twelve-page descriptive brochure. **Alderson Research Laboratories, Inc., 10 E. 38th St., New York 16, N.Y.**

Environmental Test Chamber. Designed for the production testing of jet aircraft, fuel system components under realistically simulated conditions of flight. **American Research Corp., 11 Brook St., Bristol, Conn.**

Portable Extensometer Comparator. Descriptive bulletin No. 4210. **Baldwin-Lima-Hamilton Corp., Philadelphia 42, Pa.**

Dial Indicating Extensometers. Eight-page descriptive bulletin No. 4212. **Baldwin-Lima-Hamilton Corp., Philadelphia 42, Pa.**

Model 200 Thermopile Heat-Flow Transducers. Descriptive leaflet. **Beckman & Whitley, Inc., 902 E. San Carlos Ave., San Carlos, Calif.**

Test Instruments & Accessories. Descriptive catalog No. N-1, employs a new method of listing information. **Burlington Instrument Co., 153 N. Third St., Burlington, Iowa.**

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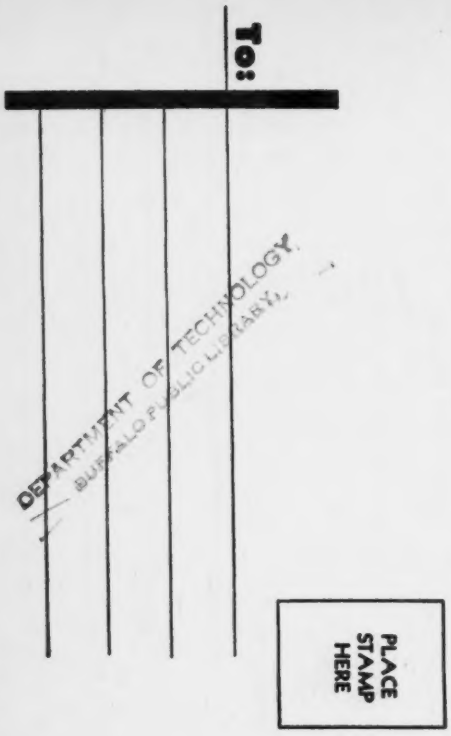

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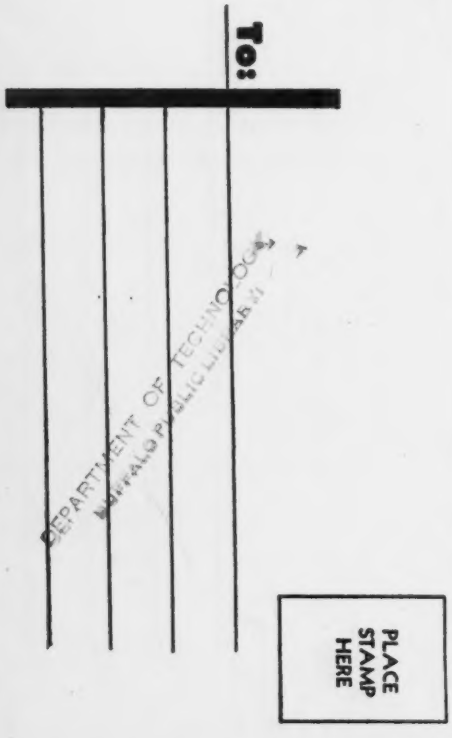

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Heat-Freeze Test Chamber. For testing jet aircraft components, this unit can drop temperatures from +600°F to −100°F in less than two hours. **Conrad, Inc., Holland, Mich.**

Recording Controllers. These instruments, designed for continuous measurement and control uninterrupted by periodic standardization, incorporate new measurement circuitry and components. Bulletin GED-2100. **General Electric Co., Schenectady 5, N.Y.**

Sweep Generator. Covers complete frequency range in a single sweep without tuning. **Kollsman Instrument Corp., 80-08 45th Ave., Elmhurst, N.Y.**

Analog-Digital Converter. Designed for use in data handling systems of digital computers. **Librascope, Inc., 1607 Flower St., Glendale, Calif.**

Data Repeaters. Repeats data that are available either as a voltage or as a mechanical shaft position to an indicator that is capable of being photographed. **Midwestern Geophysical Laboratory, Tulsa, Okla.**

Model 564 Preset Interval Generator. Designed for testing and calibrating systems that rely on precise time measurements for their operation, such as radar, sonar and certain types of telemetering equipment. **Potter Instrument Co., Inc. 115 Cutter Mill Rd., Great Neck, N.Y.**

Torsion Testers. This unit can apply and weigh load in either direction of rotation. Bulletin RT-10-54. **Riehle Testing Machines Div., American Machine & Metals, Inc., East Moline, Ill.**

Pressure Transducers. Twelve-page bulletin No. PT-1 describes instruments for the measurement of gage, differential, and absolute pressures. **Statham Laboratories, Inc., 12401 W. Olympic Blvd., Los Angeles 64, Calif.**

Type DF Heat Exchanger for Jet Engine Component Testing. Descriptive bulletin No. 105. **Thermal Research & Engineering Corp., Conshohocken, Pa.**

Miniature High-Speed Electro-Magnetic Counter. Prevents miscounts due to shock or vibration. **Unimax Switch Div., The W. L. Maxson Corp., 460 W. 34th St., New York 1, N.Y.**

Model W-9-100 FH Test Unit. For testing electrical components; features temperature range from −100°F. to +200°F. **Webber Mfg. Co., Inc., Dept. R-361, 2740 Madison Ave., Indianapolis 3, Ind.**

Thermocouple Data Book. Descriptive temperature control accessory bulletin. **West Instrument Corp., 525 N. Noble St., Chicago 22, Ill.**

NEW LITERATURE OFFERED BY ADVERTISERS

"Hyco-Span Aircraft Cable." Booklet. **American Steel & Wire Div., U. S. Steel Corp., Rm. 842, Rockefeller Bldg., Cleveland 13, Ohio** *See page 109*

Hob List of Cutters, Broaches & Special Tools. 56-page catalog. **Brad Foote Gear Works, Inc., 1309 S. Cicero Ave., Cicero 50, Ill.** *See page 12*

Engineering & Production Facilities for Jet Engine Parts. 28-page brochure. **The Cleveland Welding Co., W. 117th St. & Berea Rd., Cleveland 7, Ohio** *See page 19*

Cooling Equipment. Catalog. **Eastern Industries, Inc., 296 Elm St., New Haven, Conn.** *See page 83*

Power Supplies, Selenium Rectifiers, and Electric Cables. Literature No. E-769. **Federal Telephone & Radio Co., 100 Kingsland Rd., Clifton, N.J.** *See page 101*

Sound & Vibration Meters and Analyzing Equipment. Bulletin. **General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.** *See page 13*

Jet-Engine Gaskets. Brochure AV-1A. **Johns-Manville, Box 60, New York, 16, N.Y.** *See page 137*

Aircraft Hydraulic Accumulator. Catalog No. 1356. **Parker Aircraft Co., Section 803A, 5827 W. Century Blvd., Los Angeles 45, Calif.** *See pages 122, 123*

Air Receiver. Catalog No. 1358. **Parker Aircraft Co., Section 803A, 5827 W. Century Blvd., Los Angeles 45, Calif.** *See pages 122, 123*

Filters for Fuel, Oil, Hydraulic & Air Service. Catalog. **Purolator Products, Inc., Rahway, N.J.** *See page 119*

Oscillographic Recording. Publication entitled, "Right Angle." **Sanborn Co., Cambridge 39, Mass.** *See page 125*

Single-Row, Double-Row, and Rod-End Bearings. Catalog No. 54. **Shafer Bearing Div., Chain Belt Co., 801 Burlington Ave., Downers Grove, Ill.** *See page 91*

"Heat in Harness." Story of company's developments. **Surface Combustion Corp., Columbus 16, Ohio** *See pages 128, 129*

"Electronic Advancement." Booklet. **Thompson Products, Inc., Dept. A-8, Electronics Div., 2196 Clarkwood Rd., Cleveland 3, Ohio** *See page 96*

Aircraft Hydraulic Products. Bulletin A-5200-B. **Vickers, Inc., 1414 Oakman Blvd., Detroit 32, Mich.** *See page 97*

Absolute Pressure Controller. Publication No. TP-37-A. **Wallace & Tiernan Inc., 25 Main St., Belleville 9, N.J.** *See page 81*